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Editorial

Welcome to the first issue of BzB in 2010. The journal has been subject to major recent changes, including title and scope, editor, boards, cover design, and free availability of all contributions (open access).

The title "Bonner zoologische Beiträge" changed to "Bonn zoological Bulletin". This follows the fact that the journal's contributions, like elsewhere in biological sciences, are nowadays nearly exclusively published in English. The new title shall also contribute to increasing the journal's publicity while keeping the well-known acronym "BzB". The journal focuses now explicitly on three fields, sharpening its traditional profile as a museum journal: (1) taxonomy, (2) systematics and evolution, and (3) biodiversity and biogeography, all with respect to terrestrial animals (including fresh or brackish waters).

Publication in BzB continues to be free of charge, including colour figures, open access, retention of full rights with the authors, and production of a widely distributed print version. Manuscripts will be published online ahead of print directly after acceptance, allowing immediate public access to the latest contents. The BzB webpage (see interior cover for address) is still under revision, but contains already all published issues back to 1993. Our goal for the near future is to make the contents of all past volumes available online. In summary, the concept of BzB will guarantee fast and easy availability of the published contents.

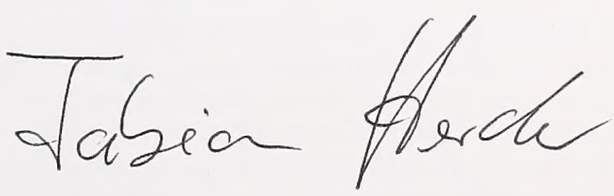
Some of the editional responsibilities changed include the editor-in-chief and the boards. Michael ("Theo") Schmitt, responsible for BzB since 2003, left Museum Koenig for Greifswald University last year. Likewise, the boards have been subject to some rearrangement. On behalf of the "BzB-team", I thank Theo and the former editorial and advisory board members for their invaluable engagement. Theo will however stay with BzB as a member of the Advisory Board. A warm "welcome on Board" to those colleagues joining or staying with the advisory or editorial team of Bonn zoological Bulletin, I am looking forwards to working with you.

Despite of the changes outlined above, the journal will retain its core strengths as a museum journal. The board members cover a wide array of expertise in zoology, and share common interests related to the journal's focus. I am convinced that this is a sound basis for the journal's future, building on the history of "Bonner zoologische Beiträge" since 1950.

Contributions published in the present issue of BzB reflect a wide array of approaches and methods applied in organismal zoology. Besides a checklist and contributions dealing with morphology, autecology or host-parasite interaction, the contents of the present issue include formal descriptions of six species new to science, including a chameleon, a gecko, a killifish (see front cover), two new species of moths, and a new fossil aquatic dance fly from Baltic amber. Taxonomic papers like these contribute to the exploration of our planet's still only partly known biota, and are increasingly not in the focus of interest of many present zoological journals. Publishing sound taxonomic work remains a core task for museum journals like BzB.

Finally, some words regarding cover design and text format. In 2003, the BzB front cover was changed from completely yellow to the design known until 2009 when the journal switched to a larger format. At this time, the additional cover space was contrasted in light grey. The present design by Uwe Vaartjes takes the next step, replacing the yellow colour completely by grey and neutral elements, and incorporates Regina Lützenkirchen's idea of including Bonn's heraldic animal, the "King (Koenig in German) of Animals". I am grateful to both for their work. Some readers and authors will have to get used to the more simplified literature style, which is a substantial reduction of the workload in production for both, authors and editors. I hope that the current revision of BzB in terms of both, focus and style, will meet the approval of the journal's audience.

With best wishes to all readers, authors and "BzB-Team" members,



Fabian Herder (Editor-in-Chief; Fish Curator at ZFMK)

Bonn, April 2010

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Description of *Callopanchax sidibei* (Nothobranchiidae: Epiplateinae), a new species of killifish from southwestern Guinea, West Africa

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Abstract. A new species of the annual killifish genus *Callopanchax* (Nothobranchiidae: Epiplateinae) is described from coastal Guinea, West Africa. It is distinguished from its congeners by morphological and colour pattern characters including up to three irregular and interrupted horizontal stripes on blue flanks in males. A preliminary DNA study indicates that it is closely related with *C. occidentalis* and *C. toddi*, which is supported by the following apomorphic characters compared to the more distantly related C. *monroviae*: a dark red or black postopercular blotch and an origin of the dorsal fin anterior to or above the first ray of the anal fin. The species first turned up in commercial imports of ornamental fish from Guinea. The local collectors, the Sidibe family, are acknowledged for sharing their knowledge on this species and their support to the second author during his collections by naming it *Callopanchax sidibei*, new species. Currently it is only known from the type locality and is endemic to Guinea.

Résumé. Une nouvelle espèce annuelle du genre *Callopanchax* (Nothobranchiidae: Epiplateinae) est décrite des côtes maritimes de Guinée, Afrique de l'Ouest. Elle se distingue de ses congénères par certains caractères morphologiques et un motif coloré comptant jusqu'à trois bandes horizontales irrégulières et interrompues sur les flancs bleus chez les mâles. Une étude ADN préliminaire indique que ce taxon est proche de *C. occidentalis* et *C. toddi*. Ceci est également supporté par les caractères apomorphes suivants – comparés à *C. monroviae*, de parenté plus éloignée: tache post-operculaire rouge sombre ou noire, et origine de la nageoire dorsale au-dessus ou antérieure au premier rayon de la nageoire anale. L'espèce a été détectée en premier dans les importations commerciales d'espèces ornementales en provenance de Guinée. *Callopanchax sidibei* sp. nov. est dédiée à la famille Sidibe, engagée dans les collectes locales, pour avoir partagé ses connaissances et avoir aidé le second auteur durant sa mission de collecte. Cette espèce endémique de Guinée n'est actuellement connue que de la localité type.

Key words. Cyprinodontiformes, *Callopanchax sidibei*, new species, taxonomy, endemic, Upper Guinea.

INTRODUCTION

The nothobranchiid genus *Callopanchax* Myers, 1933 consists of four described species of which three are currently considered valid (Costa 2008; Romand 1985, 1992; Seegers 1997; Wildekamp 1996; Wildekamp & Van der Zee 2003). They are relatively large annual killifishes, reaching up to 90.0 mm in total length according to Wildekamp & Van der Zee (2003), living in the coastal plains from southwestern Guinea and Sierra Leone to western Liberia. *Callopanchax occidentalis* (Clausen, 1966) and *C. toddi* (Clausen, 1966) were described from Sierra Leone, the latter as a subspecies of *C. occidentalis*. Some years later two further species, *C. monroviae* (Roloff & Ladiges, 1972) from Liberia, and *C. huwaldi* (Berkenkamp & Etzel, 1980) from Sierra Leone, were formally described. The latter species is currently considered a synonym of *C. occidentalis* by most authors (Costa 2008; Lazara 2001; Romand 1985; Wildekamp 1996; Wildekamp et al. 1986).

Callopanchax species are easily separated from all other species groups within the Epiplateinae by the large number of anal and dorsal fin rays and an origin of the dorsal fin anterior or slightly posterior to origin of the anal fin; in the remaining genera the dorsal fin inserts distinctly posterior to the anal fin origin. They share, with the remaining Epiplateinae, the frontal and preopercular neuromast pattern (Clausen 1966, 1967; Grimm 1974; Van der Zee 2002; Van der Zee & Wildekamp 1994), a red pigmentation pattern on the side of the head (Van der Zee 2002), and with *Archiaphyosemion guineense* (Daget,

Table 1. List of specimens used for DNA sequencing with voucher sample number, collection locality, country, and GenBank accession numbers. Accession numbers with * are published in Murphy & Collier (1997), with ** in Sonnenberg & Busch (2009). Aquarium strain means that the origin in nature for this sample is unknown.

Sample no.	species	Collection locality	Country	GenBank acc. no.
OCC GB	*Callopanchax occidentalis*	aquarium strain	Sierra Leone	U73242*
OCC1530	*Callopanchax occidentalis*	SL 03/11, Malai	Sierra Leone	GU553007
OCC1531	*Callopanchax occidentalis*	SL 89, Teme Yellah	Sierra Leone	GU553008
OCC1532	*Callopanchax occidentalis*	SL 03/19, Magbenta	Sierra Leone	FJ872034**
TOD1534	*Callopanchax toddi*	GM 97/26, Takhori	Guinea	GU553009
TOD1535	*Callopanchax toddi*	GM 97/24, Mola	Guinea	GU553010
cTOD1758	*Callopanchax* cf. *toddi*	GM 97/3, Mangata Badjana	Guinea	GU553011
SID1536	*Callopanchax sidibei*	GM 97/2, Bombokore	Guinea	GU553012
MON1533	*Callopanchax monroviae*	L 97, Paynesville	Liberia	GU553013
GER1381	*Scriptaphyosemion geryi*	SL 03/9, Robis 1	Sierra Leone	FJ872033**
GUI1404	*Archiaphyosemion guineense*	SL 93/37, Lenghe Curoh	Sierra Leone	FJ872031**

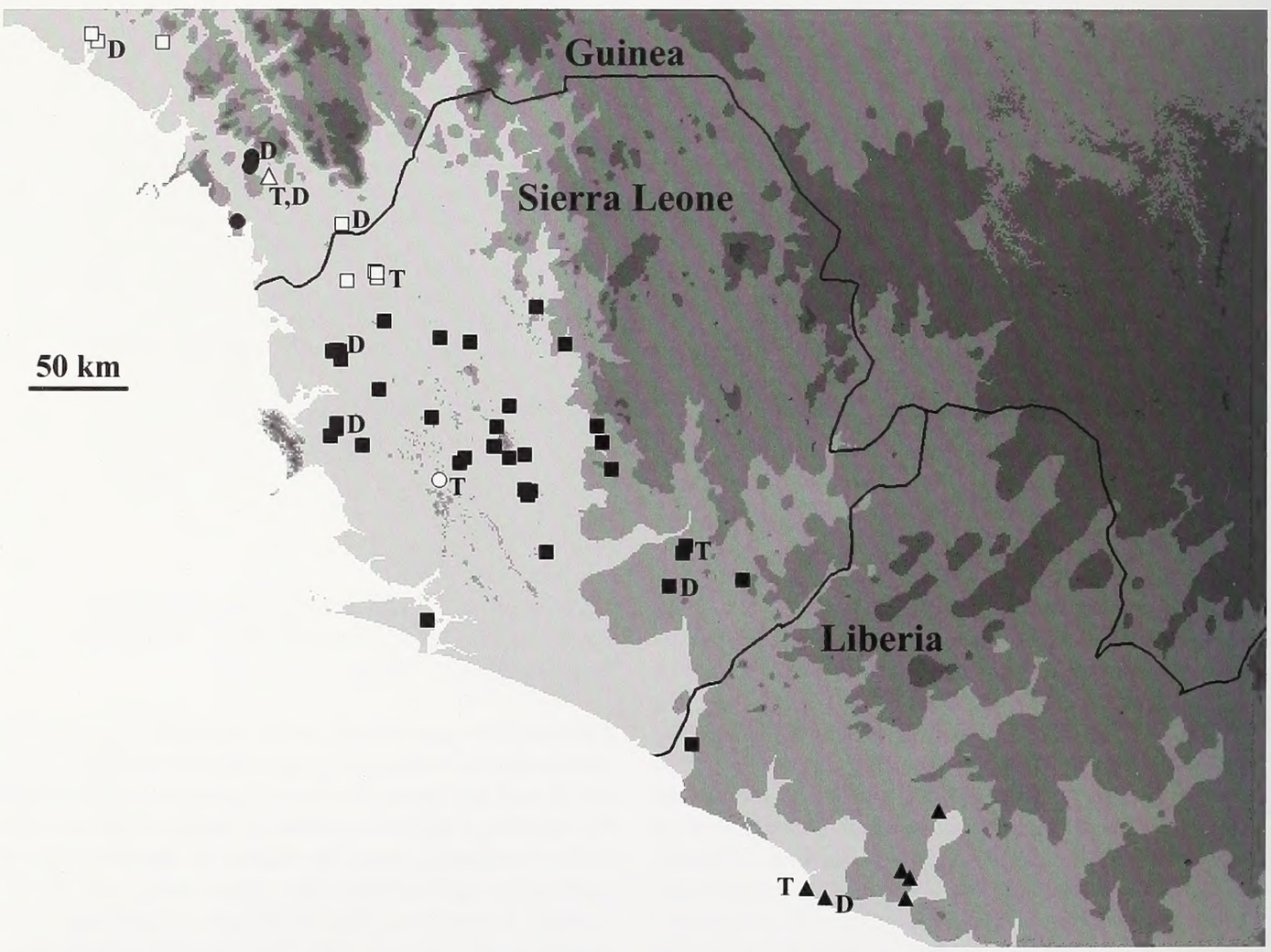

Fig. 1. Map of *Callopanchax* collection localities in coastal West Africa. The letter T indicates the respective type localities, D indicates origin of *Callopanchax* DNA samples used in this study. Black square = *C. occidentalis*, white square = *C. toddi*, black circle = *C.* cf. *toddi*, white circle = *C. huwaldi*, black triangle = *C. monroviae*, white triangle = *C. sidibei*.

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Table 2. Uncorrected p-distances for the mitochondrial LSU sequences with pairwise exclusion of missing data among nine samples of *Callopanchax*, one of *Archiaphyosemion*, and one of *Scriptaphyosemion*. The upper triangle contains the linear geographic distances between the different collection localities of the sequenced *Callopanchax* specimens, except for OCC GB, which is according to Murphy et al. (1999) an aquarium strain of unknown origin.

sample	OCC GB	OCC 1530	OCC 1531	OCC 1532	TOD 1534	TOD 1535	cTOD 1758	SID 1536	MON 1533	GER 1381
OCC 1530	1.7	–	204 km	40 km	196 km	64 km	106 km	95 km	370 km	–
OCC 1531	1.5	1.7	–	185 km	396 km	245 km	301 km	289 km	175 km	–
OCC 1532	1.9	1.3	1.5	–	230 km	103 km	144 km	132 km	340 km	–
TOD 1534	6.6	5.8	6.8	6.6	–	154 km	97 km	110 km	565 km	–
TOD 1535	5.9	5.2	6.2	6.0	1.7	–	57 km	43 km	418 km	–
cTOD 1758	6.8	5.6	6.6	6.4	2.7	1.5	–	14 km	472 km	–
SID 1536	7.6	6.7	7.5	7.1	7.5	6.5	6.2	–	458 km	–
MON 1533	14.2	12.3	12.8	13.1	12.5	12.5	12.5	13.1	–	–
GER 1381	9.6	9.7	8.7	9.3	9.5	9.7	10.1	10.6	14.2	–
GUI 1404	11.9	10.8	11.3	10.8	10.8	10.8	11.6	12.4	14.8	9.4

1954) and *Scriptaphyosemion* Radda & Pürzl,1987 a distinct constriction of the subdistal portion of the posterior arm of the parasphenoid (Costa 2009). The phylogenetic placement of *Callopanchax* within the Epiplateinae and its sister group relationship with *Scriptaphyosemion* is supported by molecular data (Murphy & Collier 1997; Murphy et al. 1999; Sonnenberg & Busch 2009).

In 1992 a scientifically unknown *Callopanchax* species turned up in a commercial import of ornamental fish from Guinea to the Netherlands. Its distinctness was first recognized by the unique colour pattern of this species (Busch 1993; Wildekamp 1996; Wildekamp & Van der Zee 2003) and was later supported by a study based on molecular data (Murphy et al. 1999). During several research trips in Guinea, the second author was able to collect specimens of this undescribed *Callopanchax,* which is herein described as *Callopanchax sidibei,* new species.

MATERIAL AND METHODS

The specimens on which the following description is based were deposited in the ichthyological collections of the Musée Royal de l'Afrique Centrale (MRAC), Tervuren, Belgium, and the Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany (ZFMK). Comparative material of the other species is listed below.

Measurements and counts are made as indicated in Sonnenberg & Busch (2009), transverse scale count was made between the anterior insertion of the pelvic fin and dorsal fin; the very small scales on the belly were not counted. Digital X-ray images of the types and some specimens of the comparative material used for unpaired fin ray and vertebrate counts were made with a Faxitron LX-60 Digital Specimen Radiography System at the ZFMK. Caudal fin ray counts were only made from X-ray images and include all visible rays.

We prepared a preliminary DNA dataset of a fragment of the mitochondrial large ribosomal subunit (16S rDNA) for a small number of specimens, including three of *C. occidentalis* from Sierra Leone, one sequence of *C. occidentalis* from GenBank (accession number U73242, Murphy & Collier 1997), two specimens of *C. toddi* and one of *C.* cf. *toddi* from Guinea, one specimen of each *C. monroviae* and *C. sidibei*, new species, and, as an outgroup, *Archiaphyosemion guineense* and *Scriptaphyosemion geryi* (Lambert, 1958). The latter two are the type species of the respective genera. Specimens are listed with locality information and GenBank accession number in Table 1, methods for DNA extraction, amplification and sequencing of the 16S rDNA fragment are provided in Sonnenberg & Busch (2009), where also some of the sequences were published. Resulting sequences were aligned with ClustalX 1.8 (Thompson et al. 1997) and checked by eye in BioEdit 7.0.5.3 (Hall 1999). Sequences were tested for the anti-G bias characteristic of mitochondrial DNA (Zhang & Hewitt 1996). Uncorrected p-distances with the pairwise deletion of missing data were calculated in Mega 4.1 beta 3 (Tamura et al. 2007) and are given in Table 2.

Analyses of sequence data were made with PAUP 4.0b10 (Swofford 1998) by maximum parsimony and with MrBayes 3.1.2 (Huelsenbeck & Ronquist 2001) by a

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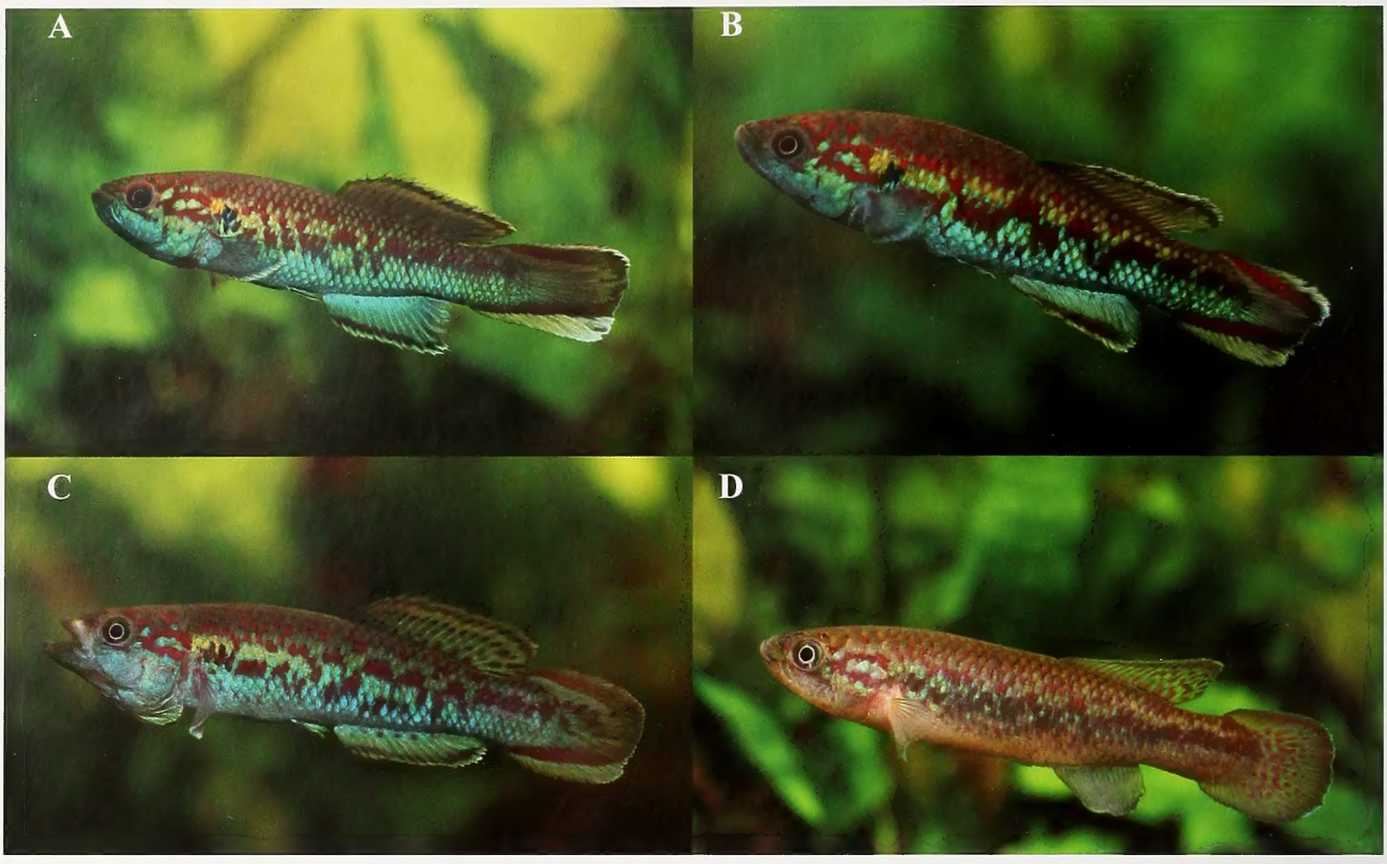

Fig. 2. A) Holotype of *Callopanchax sidibei*, male, ZFMK 41613, 58.5 mm SL. B) Paratype of *Callopanchax sidibei*, male, ZFMK 41614, 47.0 mm SL. C) *Callopanchax sidibei*, male with red dots in the anal and caudal fin, not preserved. D) Paratype of *Callopanchax sidibei*, female, ZFMK 41615, 55.4 mm SL.

Bayesian approach. Maximum parsimony analyses were done with the exclusion of uninformative positions, gaps were coded as a fifth character state, and heuristic tree searches were performed with random addition of sequences for 1,000 replicates. Bootstrapping was performed with the random addition of sequences for 100 replicates and 10,000 bootstrap replicates. Bayesian analyses were performed with the number of generations set to 10,000,000, with sampling every 1,000 generations, and the results of the first 1,000,000 generations were discarded as a burn-in time after checking that the runs had reached the stationary phase at this point of the analysis. We performed two runs for this dataset, one with two parameter models (Nst 2) and one with six parameter models (Nst 6), settings for rate=gamma and ngammacat=4. We chose to perform these two runs to check if there are serious differences in the results due to potential under- or overparametrization, especially because of the small dataset with large genetic divergences (Table 2). We consider only nodes with ≥ 75 % bootstrap support and ≥ 95 % posterior probabilities as supported by the data.

Additional information for the collection localities in Table 1 can be found in the comparative material list. Collection points in Figure 1 are from museum collection data as accessed via Fishbase (Froese & Pauly 2009), from Huber (2007), and collection data of the second author. We adopted, as a species concept, the definition by Moritz et al. (2000) which „...recognize as species geographically bounded sets of populations that are distinct for morphological traits or are reproductively isolated from congeners, with or without corresponding molecular divergence...".

RESULTS

Callopanchax sidibei, new species

(Fig. 2A–D, Table 3)

Roloffia sp. „Guinea, CI 92": Busch (1993), p. 64.
Fundulopanchax species aff. *toddi*: Wildekamp (1996), pp. 212–213.
Callopanchax sp. Guinea: Wildekamp & Van der Zee (2003), pp. 381–383.
Callopanchax huwaldi (non Berkenkamp & Etzel, 1980): Neumann (2005), misidentification in fig. caption p. 48.

Holotype. ZFMK 41613, male, 58.5 mm SL, Guinea, Guinée maritime, Kindia region, small river and adjacent pools and ditches in a secondary forest (9°32.71' N,

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Table 3. Morphometric and meristic data of *Callopanchax sidibei*. All measurements in percentages of standard length except standard length in mm. Fin ray counts were made on X-rays and include all visible rays. SD = standard deviation.

	Holotype	♂ Types mean	♀ Types mean	all Types mean	all Types range	all Types SD
Standard length	58.5	48.4	50.7	49.7	39.0–59.9	6.8
Total length	124.8	124.6	122.7	123.5	117.1–132.5	4.5
Head length	28.4	29.2	29.1	29.1	27.7–30.5	0.9
Predorsal fin distance	56.7	57.6	60.1	59.0	55.4–63.2	1.9
Prepelvic fin distance	54.1	52.0	52.7	52.4	49.1–56.6	2.0
Preanal fin distance	62.9	62.5	64.2	63.5	60.1–68.9	2.3
Greatest body depth	24.3	23.3	22.3	22.7	20.0–25.8	1.6
Depth of caudal peduncle	13.3	13.2	12.1	12.6	10.7–14.6	1.0
Length of caudal peduncle	23.1	21.6	22.1	21.9	17.8–25.1	1.7
Base of dorsal fin	28.3	28.2	25.7	26.8	23.5–30.7	1.9
Base of anal fin	23.2	23.1	18.2	20.3	17.6–24.6	2.6
Eye diameter	7.2	6.8	6.8	6.8	6.1–7.6	0.4
Interorbital distance	13.7	12.1	11.7	11.9	10.3–13.7	0.8
Dorsal fin rays	19	19.8	19.8	19.8	19–21	0.8
Anal fin rays	17	17.9	18.1	18.0	17–19	0.6
Dorsal / anal fin position	-2	-2.8	-3.2	-3.0	-2– -4	0.7
Caudal fin rays	33	32.0	31.8	31.9	29–34	1.2
Total number of vertebrae	33	33.1	32.6	32.8	32–34	0.7
Vertebrae with pleural ribs	15	15.2	14.8	15.0	14–16	0.7
Vertebrae with haemal spines	18	17.9	17.8	17.8	17–19	0.6
Lateral line scales	34+4	33.2+3.8	33.1+3.5	33.1+3.6	32-34+3-5	0.9+0.6
Transverse row of scales	12	11.2	10.8	11.0	10–13	0.8
Scales around caudal peduncle	16	15.9	15.8	15.9	15–16	0.4

13°14.51' W), close to the small village Bombokoré, about 3 km from the closest larger village Fandi, collection locality GM 08/2, E. Busch and B. Wiese, 25.10.2008, Figure 2A.

Paratypes. ZFMK 41614–41615, 1 male, 47.0 mm SL, 1 female, 55.4 mm SL, paratopotypes, collected with holotype, Figure 2B & D.
ZFMK 41616–41628, 5 males, 8 females, 39.0–58.9 mm SL, paratopotypes, collected with holotype.
MRAC 2010–02–P–1–5, 2 males, 3 females, 46.3–59.9 mm SL, paratopotypes, collected with holotype.

Diagnosis. *Callopanchax sidibei* (Fig. 2A–D) is, together with *C. toddi* (Fig. 3A–F) and *C. occidentalis* (Fig. 4A & B), distinguished from *C. monroviae* (Fig. 5A–C) by insertion of first dorsal fin ray slightly anterior to first anal fin ray versus a posterior insertion. The former three species are also distinguished from *C. monroviae* by a dark red to black postopercular blotch above insertion of pectoral fin versus absence and a dark or black blotch on the anterior dorsal fin rays instead. The postopercular blotch is present in females of *C. sidibei*, *C. occidentalis,* and *C. toddi* but often only faint; the dark blotch on anterior dorsal fin in *C. monroviae* may not be visible in females. *Callopanchax sidibei*, *C. occidentalis*, and *C. toddi* males have an anal fin with a white or bluish-white margin and usually only a small number of red dots or blotches on fin center; no horizontal red band or only traces of red under the eye from lower lip to posterior border of opercle; postopercular red pigmentation on flank formed by up to three irregular red horizontal bands interrupted into blotches. Males of *C. monroviae* have a dark or dark-red anal fin margin, proximal red dots, blotches or broad vertical streaks, and streaks between fin rays on distal part of anal fin; a more or less complete red band from snout under the eye and often extending on side to origin of pelvic fin; postopercular red pigmentation consists of incomplete rows of small red dots on anterior side and less and irregularly distributed red dots or a pattern of incomplete and irregular vertical stripes on posterior side. Males of *C. sidibei* can also be distinguished from *C. monroviae* by

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Fig. 3. A) Male of *Callopanchax* cf. *toddi*, Mangata Badjana, Guinea, collection locality GM 08/3 (= GM 97/3). B) Female of *Callopanchax* cf. *toddi*, Mangata Badjana, Guinea, collection locality GM 08/3 (= GM 97/3). C) Male of *Callopanchax toddi*, Mola, Guinea, collection locality GM 09/17 (= GM 08/4 & GM 97/24). D) Female of *Callopanchax toddi*, Mola, Guinea, collection locality GM 09/17 (= GM 08/4 & GM 97/24). E) Male of *Callopanchax toddi*, Lamayah, Guinea, collection locality GM 08/11. F) Male of *Callopanchax toddi*, Takhori, Guinea, collection locality GM 09/12 (= GM 08/9 & GM 97/26).

body colouration which is mainly blue to blue-green on sides and dorsally often a golden sheen to the anterior, versus anteriorly pale blue to blue-green and dorsal and posterior half of body reddish, reddish-brown or orange, or in the blue form body completely pale to grey-blue (Fig. 5A–C).

Callopanchax sidibei can be distinguished from males of *C. occidentalis* and *C. toddi* by up to three irregular and interrupted horizontal stripes on flanks, an absence of vertical dark red or reddish-brown stripes or broad blotches on sides and a mainly blue to blue-green body colour versus dark brown, brown or red vertical stripes or blotches

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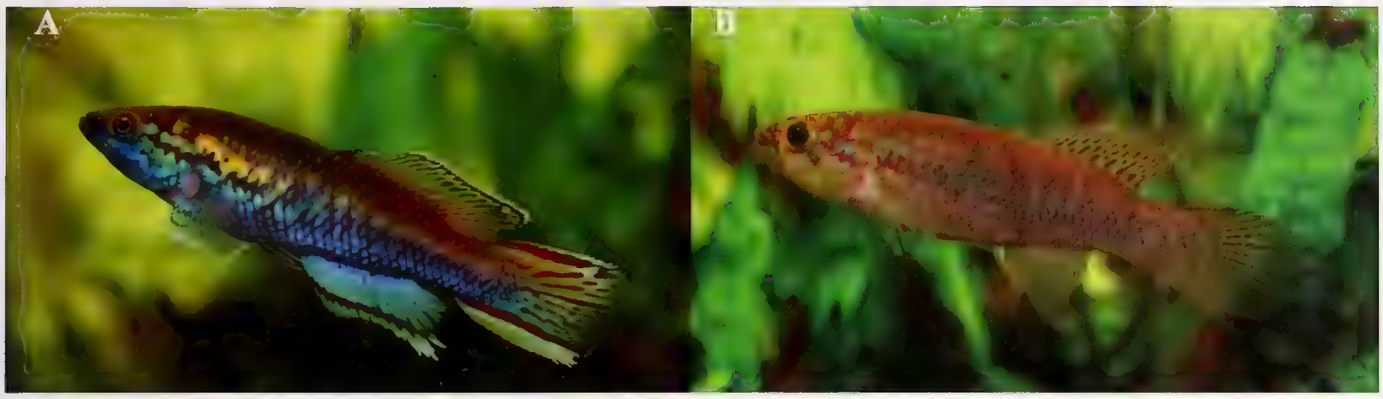

Fig. 4. A) Male of *Callopanchax occidentalis*, Malai, Sierra Leone, collection locality SL 03/11 (= SL 93/54). B) Female of *Callopanchax occidentalis*, Malai, Sierra Leone, collection locality SL 03/11 (= SL 93/54).

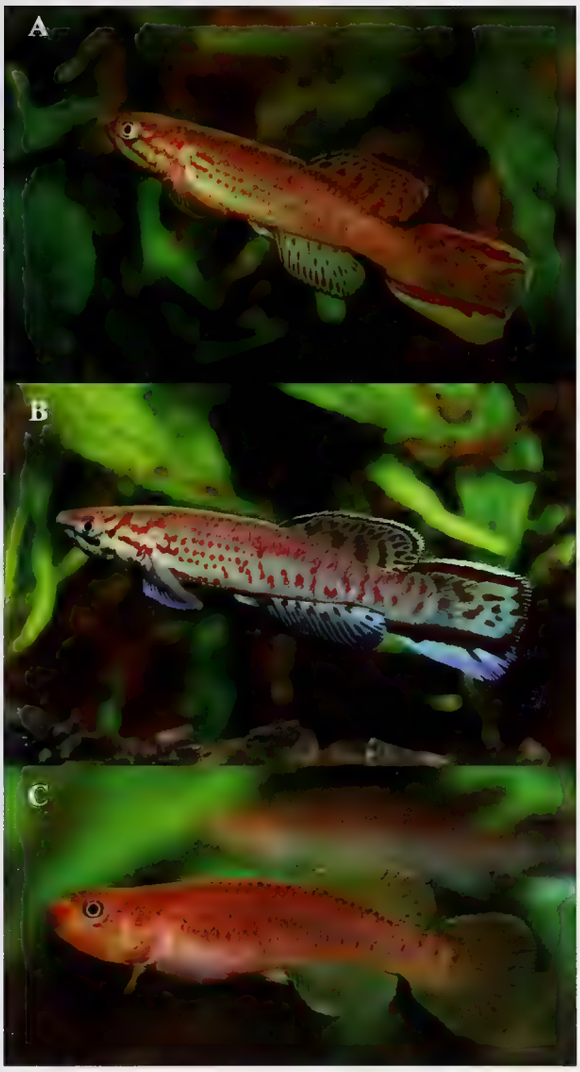

Fig. 5. A) Male of *Callopanchax monroviae*, aquarium strain from Paynesville, Liberia, collection locality L 97, red form. B) Male of *Callopanchax monroviae*, aquarium strain from Paynesville, Liberia, collection locality L 97, blue form. C) Female of *Callopanchax monroviae,* aquarium strain from Paynesville, Liberia, collection locality L 97.

and a more reddish brown or copper to golden body colour with blue only on ventral side. Exceptions are populations with rare blue males in *C. occidentalis* and, if valid, *C. huwaldi*, which show the same pattern as the 'typical' form but lack orange and yellow pigments, but not the red pigmentation and the dark vertical stripes or blotches on posterior side (e.g. Berkenkamp & Etzel 1980; Eberl 1999, pictures of *C. occidentalis* from Mabeimah on p. 65; Roloff 1976).

Large males of *C. sidibei* show only a slightly rugged anal and dorsal fin border and rounded or slightly pointed fin tips versus more pronounced rugged fin borders in most *C. occidentalis* and *C. toddi*, especially the posterior tip of the anal fin, which can show filamentous extensions.

Females of *C. sidibei* can be distinguished from *C. occidentalis* and *C. toddi* females by mid-laterally blue to blue-green coloured scales and the absence of the dark brown vertical stripes or blotches, similar as in males versus blue to blue-green coloured scales only on anterior side, often with short vertical dark blotches dorsally on side. They are distinguished from females of *C. monroviae* by their pigmentation pattern of red horizontal stripes with broad blotches versus more regular horizontal rows of small red dots and the absence of metallic blue to blue-green coloured scales on side in *C. monroviae*.

Description. See Fig. 2A–D for general appearance and Table 3 for morphometric and meristic data of the types. *Callopanchax sidibei* (Fig. 2A–D) shares with its congeners the following combination of diagnostic characters within the Epiplateinae: large and robust species, dorsal and anal fins with a high number of fin rays, origin of dorsal fin close to origin of anal fin. A species with strong sexual dimorphism, adult males usually larger, with larger fins and more colourful than females. Maximum ob-

served SL in males 59.9 mm, in females 59.0 mm. Body cylindrical, outline from tip of snout to posterior end of dorsal and anal fin convex, on caudal peduncle dorsally and ventrally slightly concave to nearly straight. Greatest body depth approximately at half distance between origins of pectoral and pelvic fins.

Snout slightly pointed, mouth directed upwards, lower jaw longer than upper jaw; many irregularly distributed unicuspid, slightly curved teeth of different size, a small number of larger ones on the outer row of upper and lower jaw. Closed frontal neuromast system in one groove, preopercular neuromast system with 5 pores.

Total number of vertebrae 32–34, number of vertebrae with pleural ribs 14–16, with haemal spines 17–19. The X-ray images indicate that in about half of the studied specimens the hypural plates are fused, as no gap or indication of overlap is visible.

Fins in males slightly larger than in females, base of dorsal mean value 28.2 % of standard length (SL) in males versus 25.7 % SL, base of anal in males 23.1 % SL versus 18.2 % SL in females. Dorsal and anal fin rounded or slightly pointed, no long filamentous extension, fin insertion in both sexes posterior to mid-body. In large adult males, dorsal and anal fin rays sometimes protrude from the fin membran, giving the impression of a rugged fin border. Papillae on anal fin rays in males. First 2–4 dorsal fin rays anterior of origin of anal fin. Dorsal fin rays 19–21, anal fin rays 17–19. Caudal fin rounded or slightly truncated, 29–34 fin rays. The single specimen with 29 caudal fin rays has a small gap between the anterior dorsally situated rays explaining the comparatively low value. Pectoral fin origin on ventral half of side, posterior of opercle, rounded, extending posteriorly, not reaching origin of pelvic fin. Pelvic fin small and slightly pointed, not or just reaching anal fin.

Scales cycloid, body and head entirely scaled except throat, scales dorso-anteriorly larger then ventrally and posteriorly, frontal squamation of G-type, scales on lateral line 32-34 + 3-5 on caudal fin base, not all scales along lateral line with small grooves in center. Transverse row of scales above pelvic fin 10–13, circumpeduncular scale row 15–16.

Live colouration. Males. (Fig. 2A–C) Dorsal from head to dorsal fin brown, some scales on back with red dots or scale borders, forming an irregular reticulated pattern to the end of the caudal peduncle; flanks blue to blue-green, dorsolaterally with a metallic copper or golden sheen on scales, belly blue to bluish-grey.

Red pigmentation pattern on head posterior of the eye typical for Epiplateinae (Van der Zee 2002) with two posterior directed horizontal red stripes, originating from one point posterior of the eye to posterior border of opercle, and two more or less complete vertical stripes dorsally.

On flanks three interrupted and irregular red stripes, upper and lower stripes only extending up to the posterior insertion of dorsal fin, only the middle stripe, positioned slightly above mid-line of body, extends to the end of the caudal peduncle, in some males the dorsolateral stripe only consists of a small number of red dots or red scale borders.

Posterior of the opercle and above insertion of pectoral fin usually 2–3 scales in two neighbouring rows with broad black or dark red margin, forming a black or dark red blotch.

Unpaired fins blue to blue-green, with white or, rarely, yellow-white margins and red submarginal stripe. Red pigmentation pattern on unpaired fins variable. Dorsal fin with red dots or short streaks between fin rays, below red submarginal band a whitish zone. Anal fin without or only with little red pigmentation beside submarginal red stripe, in some males a proximal row with a small number of red dots (Fig. 2C). Caudal fin in some males with red dots or blotches, lower white margin broader then upper and in some specimens slightly yellow-white. In males with a more rounded caudal fin shape marginal and submarginal stripes can be closed on posterior end of fin, in males with a more truncate fin shape they end on the posterior fin border (Fig. 2A–C). Pelvic fins bluish, with red submarginal and white marginal stripe, pectoral hyaline with a white or blue-white margin.

Females. (Fig. 2D) Body brown to light brown, dorsally darker then ventrally, sometimes with a golden colour sheen on anterior side. Scales dorsally and laterally with dark border, forming a reticulate pattern. Lateral red pigmentation pattern similar to males, usually less pronounced and paler. Broad dark brown to brownish-grey lateral stripe from posterior border of operculum above origin of pectoral fin to posterior end of caudal peduncle on upper half. This stripe is not always visible and especially pronounced in stressed specimens. On upper half of opercle, posterior of the eye, extending along the dark stripe on the side irregularly distributed scales with metallic blue or blue-green colour, with the highest density anteriorly. Fins except pectoral light brown and slightly hyaline, unpaired fins with a whitish margin, on dorsal and caudal with pale red submarginal line. Dorsal and caudal fin with red dots, on dorsal sometimes restricted to fin base. Pectoral fin transparent with whitish to light blue margin.

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Preserved in ethanol. Males. Head dark grey, body dark brown to grey, some traces of red dots and blotches on side, belly whitish, beige, or greyish, a ventral dark stripe posterior to level of pectoral fin insertion to anterior origin of anal fin. Fins pale grey with a dark submargin and small whitish margin, except caudal fin with a ventral broad and dorsal thin whitish margin, posterior border dark brown to reddish.

Females. Head laterally and dorsally dark grey, chin with a dark blotch on ventral inner side of lower lip, body dorsally darker grey or brown, a dark stripe from posterior border of opercle to origin of caudal fin, dark stripe dorsally with a sharp border, ventrally diffuse; below this stripe brown, anterior ventral side and belly whitish to light brown, on side traces of red spots and blotches. Fins light grey with a dark border, sometimes with a small white margin, in dorsal and caudal fin traces of red spots, very rare with proximal single row of red dots in anal.

Etymology. The new species is named after Mr. Samba Sidibe and his family, who first collected this fish and made specimens available for the ornamental fish trade. It is named in acknowledgement of their high interest in this species, their effort for a sustainable use and protection of the habitat, and providing important information for the description.

Distribution and habitat. Currently *C. sidibei* is only known from the type locality close to the small village Bombokoré, despite some effort to find further occurrences of this species in the vicinity. Bombokoré is the spelling in the Sousou language, it might have a different spelling on maps or gazetteers.

The habitat is a depression with small water bodies, ditches and connected pools in a secondary forest adjacent to a small creek. The water in the creek is only slowly flowing and stagnant in pools and ditches. During the first collection in 1997, the second author measured an air temperature of 36°C, the water temperature in the creek was 27°C and 29°C in ditches, pH was about 5.2, conductivity 10µS/cm. Water in the ditches was about 20–30 cm deep and clear, the bottom consists of of sand and some stones with a layer of decaying leaves and wood with no aquatic vegetation. Herbaceous plants were found along the edges. *Callopanchax sidibei* and *Epiplatys fasciolatus* (Günther, 1866) were found in ditches and pools with standing water. In places with only grass and no leaf cover, only *Scriptaphyosemion geryi* was recorded.

During the collection in 2008, the depression was flooded. The stagnant or slowly flowing water was shaded by herbaceous vegetation and young trees on edges and some aquatic vegetation, especially *Nymphea*. Air temperature was 31°C, water temperature 27°C, water depth about 60–80 cm maximum. Interestingly the specimens caught in 2008 were of different size, from juveniles with about 2.5 cm total length to full grown adults, and in good condition, whereas in 1997 all were fully grown and showed first signs of ageing. During the last visits in 2008 and 2009 only a little human impact on the forest could be detected.

Callopanchax sidibei seems to prefer shaded areas of the water bodies with slow flowing or standing water. However, the life cycle of this species depends on the flowing water of the creek, because there is a seasonal connection between the creek and the pools and ditches. During the rain season the creek floods the depression and provides habitat, fresh water and food sources for the growing juveniles. Later, the inflow is reduced and isolated or partially connected pools and ditches are formed, which dry out during the dry season. Within these water bodies reproduction takes place and adult fish most likely die during the dry season. *Callopanchax sidibei* is, like its congeners (e.g. Scheel 1968; Wildekamp 1996), an annual species with eggs showing a prolonged development of 2–9 month, apparently an adaptation to temporary water bodies. However, some adults might move during the dry season into the flowing creek, which is supported by the observation of the local people.

DNA analyses. The complete alignment of the mitochondrial large ribosomal subunit for 11 specimens contains 530 bp including gaps, the sequence lengths without gaps ranges between 518–526 bp; the GenBank sequence (U73242) is 46 base pairs shorter, missing positions were filled with N. Of the 530 bp 133 are variable and 61 were parsimony informative, calculated without gaps. All sequences show an anti-G bias typical for mitochondrial sequences (Zhang & Hewitt 1996).

Calculated intraspecific p-distances for the samples of *C. occidentalis* as well as *C. toddi* and *C.* cf. *toddi* (Table 2) are higher than for the corresponding fragment in *Nimbapanchax* (Sonnenberg & Busch 2009), ranging from 1.3–2.7, which is in the range of the interspecific p-distances within the latter genus. Interspecific p-distances within *Callopanchax* range from 5.2–7.6 between *C. occidentalis*, *C. toddi*, and *C. sidibei*, and up to 14.2 with the inclusion of *C. monroviae*. Interestingly the intraspecific distances, even between geographically close collection localities, are comparatively high (Table 2).

In all resulting phylogenies, *C. monroviae* splits off first with respect to the remaining three taxa, which form an unresolved trichotomy (Fig. 6); this is congruent with the observed differences in colouration and morphology. As in Murphy et al. (1999), the distinct position of *C. sidibei*

is supported. However, these results should be seen as a first preliminary insight into the species relationships in *Callopanchax* as the dataset is currently too small for developing well supported, stable phylogenetic hypotheses, and should be expanded both in number of specimens and genes in further analyses, especially with regard to the large genetic distances between the species.

DISCUSSION

The distinctness of *Callopanchax sidibei* with regard to its congeneric species was recognized very early after the first commercial import to the Netherlands (Busch 1993; Wildekamp 1996), but nothing was known about its origin, distribution, and habitat. The second author was able to collect this species in 1997 with the help of the Sidibe family, who are engaged in the ornamental fish trade and were probably the first to export this species from Guinea. *Callopanchax sidibei* is currently only known from one locality; other *Callopanchax* collections in this area contain either *C. toddi* or *C.* cf *toddi* (Fig. 1).

Interestingly in wild males two different caudal fin shapes exist: a more elongate and truncate form (Fig. 2A) and a shorter and rounded one (Fig. 2C), of which only the latter turns up in aquarium bred specimens. In general the red pigmentation pattern on the body and fins is quite variable (Fig. 2A–C).

As for *C. toddi*, currently no other colour morphs are known from *C. sidibei*, unlike the orange (or red) and blue phenotypes of *C. occidentalis* and *C. monroviae* (Fig. 5A–C, see also figures e.g. in Eberl 1999; Seegers 1997; Van den Nieuwenhuizen 1974; Wildekamp 1996). These colour morphs are usually sympatric with the more common form which is the blue morph in *C. monroviae* and the red in *C. occidentalis* (Berkenkamp & Etzel 2003; Wildekamp 1996; Wildekamp & Van der Zee 2003). One species, *C. huwaldi*, which is considered as junior synonym to *C. occidentalis*, differs from the latter species in external appearance only by the absence of yellow and orange pigments (see colour figure in Roloff 1976, p.523). There is still some discussion about the validity of the species; protein electrophoretic data and cross-breeding experiments by Berkenkamp & Etzel (2003) and Etzel & Berkenkamp (1981) show differences between the two species, but protein electrophoretic data by Romand (1985) do not differ. DNA data by Murphy et al. (1999) place *C. huwaldi* close to *C. occidentalis*, but the data set was to limited for further conclusions.

Up to now, several other collections from an area close to the type locality of *C. huwaldi* were made e.g. by the second author, which contained small numbers of blue males between red ones. Roloff (1974) reported a sympatric occurrence of *C. occidentalis* and *C. toddi*, collected by Chaytor close to Njala, which is also within this area, and is most probably an occurrence of sympatric red and blue *C. occidentalis* males and not a sympatry of the reported species.

The second author was able to breed the red and the blue phenotype from Largo (SL 89) and Mabeimah (SL 93/46) several times in the aquarium and it seems that the blue phenotype is recessive with regard to the red, which is supported by the observation that the blue phenotype is usually rare in nature (pers. observation E. Busch). The females of both forms show no differences.

In case of *C. sidibei* it can be excluded that it is just a colour form of *C. toddi* or *C. occidentalis*. Beside differences in body colouration the red pigmentation pattern also differs from all populations of *C. toddi* and *C. occidentalis,* whereas in the cases of *C. monroviae* and *C. occidentalis,* including *C. huwaldi,* only the yellow and orange pigments are lost but the red pigmentation pattern is stable. This is also supported by DNA data, in which *C. sidibei* is placed as separate lineage related to *C. occidentalis* and *C. toddi* (Fig. 6 and Murphy et al. 1999).

The recent collections of the second author in Guinea provide additional information about the distribution of *Callopanchax*, and extends the areal of the genus further northwards along the coast (Fig. 1). It should be noted that several of the populations collected so far show combinations of characters, which do not agree with the current diagnoses of *C. toddi* and *C. occidentalis* (Clausen 1966; Wildekamp & Van der Zee 2003). Further studies will show whether these species are more variable than previously known, or if the divergent populations represent distinct units which might be accepted as separate species. These fishes are currently listed here as *C.* cf. *toddi* (see Fig. 1 and as example Fig. 3A & B).

COMPARATIVE MATERIAL

Callopanchax huwaldi: ZFMK 12663–12667, Sierra Leone, 20 km von Moyamba, Ngabu (8°10' N, 12°28' W).

Callopanchax monroviae: ZFMK 41629–41630, Liberia, Paynesville, L 97 (6°17' N, 10°43' W); ZFMK 41631–41634, aquarium bred, strain from Liberia, Paynesville, L 97 (6°17' N, 10°43' W); RS1533, DNA sample, aquarium bred, strain from Liberia, Paynesville, L 97 (6°17' N, 10°43' W).

Callopanchax occidentalis: ZFMK 41635–41643, first generation after collection, Sierra Leone, SL 89 Largo

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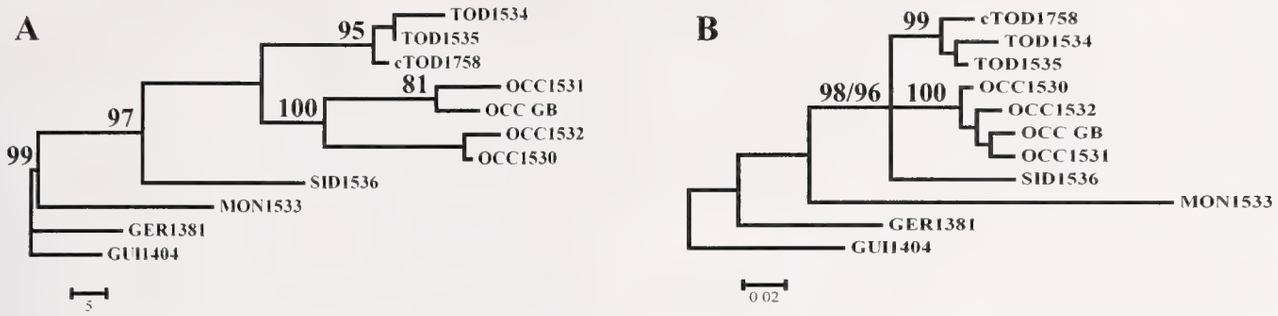

Fig. 6. Results of the maximum parsimony (A) and Bayesian (B) analyses of the mitochondrial large ribosomal subunit (16S) fragment. Numbers on nodes are bootstrap values in A and posterior probabilities in B. In the latter, the first values are from the analysis with Nst=2, the second values from the analysis with Nst=6, if both have the same value, only one value is given. Only for nodes with ≥ 75 % bootstrap support and ≥ 95 % posterior probabilities values are shown.

(8°16' N, 12°09' W); ZFMK 41644–41647, Sierra Leone, SL 89 Magbenta (8°24' N, 12°56' W); ZFMK 41648–41654, aquarium bred strain from Sierra Leone, SL 89 Ngabu (8°15' N, 12°22' W); ZFMK 41655–41657, Sierra Leone, SL 89 Romeni (8°53' N, 12°43' W); ZFMK 41658–41671, Sierra Leone, SL 89 Teme Yellah (7°41' N, 11°25' W); RS1531, DNA sample, Sierra Leone, SL 89 Teme Yellah (7°41' N, 11°25' W); ZFMK 41672–41674, Sierra Leone, SL 89 Waanje River (7°50' N, 11°22' W); ZFMK 41675, Sierra Leone, Ma Barie, SL 93/39 (8°25' N, 11°45' W); ZFMK 41676–41681, Sierra Leone, Mogbomoh Village, Saspoor Water, SL 99/12 (8°20' N, 12°49' W); ZFMK 41682, Sierra Leone, Brama School, SL 03/7 (8°22' N, 12°58' W); ZFMK 41683–41688, Sierra Leone, Malai, SL 03/11 (8°45' N, 12°56' W); ZFMK 41689–41697, Sierra Leone, Rowala, SL 03/12 (8°47' N, 11°54' W); ZFMK 41698–41704, Sierra Leone, Magbenta, SL 03/19 (8°24' N, 12°56' W).

Callopanchax toddi: ZFMK 41705–41715, Guinea, Mola, GM 08/4 (9°20' N, 12°55' W); ZFMK 41716–41723, Guinea, Takhori, GM 08/9 (10°09' N, 14°01' W); ZFMK 41724–41728, Guinea, Katamara, GM 08/10 (10°11' N, 14°03' W); ZFMK 41729–41735, Guinea, Lamayah, GM 08/11 (10°09' N, 13°44' W); ZFMK 41736–41739, Sierra Leone, Sentai, SL 93/15 (9°04' N, 12°53' W).

Callopanchax cf. *toddi*: ZFMK 41740–41744, Guinea, Gbeteyah Moribayah, GM 08/1 (9°36' N, 13°20' W); ZFMK 41745–41751, Guinea, Mangata Badjana, GM 08/3 (9°38' N, 13°19' W); ZFMK 41752–41755, Guinea, Yirah, GM 08/8 (9°37' N, 13'19' W); ZFMK 41756–41757, Guinea, Kabak, GM 08/12 (9°21' N, 13°23' W); ZFMK 41758–41763, Guinea, Kabak, GM 08/13 (9°21' N, 13°23' W).

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Gekko ulikovskii Darevsky & Orlov, 1994: a junior synonym of *Gekko badenii* Szczerbak & Nekrasova, 1994

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In Vietnam, a total of seven species of *Gekko* are currently recognized: *G. badenii*, *G. chinensis*, *G. gecko*, *G. grossmanni*, *G. palmatus*, *G. scientiadventura*, and *G. ulikovskii* (Rösler et al. 2004; Nguyen et al. 2009). Both *Gekko badenii* and *G. ulikovskii* were simultaneously described in 1994 based on the type series collected from Ba Den Mountain in Tay Ninh Province and "Gilai-Con Tum Province" (now Kon Tum Province) near the border with Laos and Cambodia, respectively (Darevsky & Orlov 1994; Szczerbak & Nekrasova 1994). The diagnostic characters of *G. badenii* and *G. ulikovskii* obtained from the original descriptions are presented in Table 1.

In the key to the species of *Gekko* from Vietnam, Rösler et al. (2004) distinguished these two species by the number of interorbital scales (30–37 in *badenii* versus 40–46 in *ulikovskii*). Based on the original descriptions, *G. badenii* further differs from *G. ulikovskii* by the following characters: smaller SVL (51.5–76.5 mm in *G. badenii* vs. 87–108 mm in *G. ulikovskii*), smaller ratio of SVL/TaL (0.82 in *G. badenii* vs. 0.94–1.24 in *G. ulikovskii*), and larger number of precloacal pores (14–18 in *G. badenii* vs. 10–15 in *G. ulikovskii*). During recent field work in southern Vietnam, a series of *G. badenii* was collected in October 2004 by Nguyen Huu Dat from the type locality on Ba Den Mountain, Tay Ninh Province, and was subsequently deposited in the Institute of Ecology and Biological Resources, Hanoi, Vietnam (IEBR 1555, 1562–1564, 1566). Our own examination of this new collection compared with two paratypes of *G. ulikovskii* deposited in the collection of the Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany (ZFMK 55110–55111) revealed that there are no distinct differences in morphology between these two species. All

Fig. 1. *Gekko badenii* (IEBR 1562) from Ba Den Moutain, Tay Ninh Province, Vietnam (alive animal)

Fig. 2. *Gekko badenii* (IEBR 1562) from Tay Ninh Province (a) and *Gekko ulikovskii* (Paratype: ZFMK 55110) from Kon Tum Province (b) (preserved specimens).

diagnostic characters obtained from the original descriptions and examined specimens resemble each other or rather overlap: SVL (51.5–106.0 in *G. badenii* and 87.0–108.0 in *G. ulikovskii*), ratio of SVL/TaL (0.81–1.28 in *G. badenii* and 0.94–1.24 in *G. ulikovskii*), interorbital scales (30–39 in *G. badenii* and 35–46 in *G. ulikovskii*), precloacal pores (12–18 in *G. badenii* and 10–15 in *G. ulikovskii*), dorsum dark grey with 6–8 light bands in both species, for further comparison see Table 1. It is noted that our scalation counts for two paratypes of *G. ulikovskii* (ZFMK 55110–55111) are a bit different from the original description: interorbitals (number of scales between middle orbitals, not including granular scales on upper eyelids) 35–38 versus 40–41 in the original description; scales around midbody (number of scales around body at the position between axilla and groin): 114–118 versus 131–136 in the original description. Moreover, the character "scales around midbody" was erroneously noted as "dorsals around midbody–DoM" for 11 paratypes [Table 1, p. 74] by Darevsky & Orlov (1994). Although these authors did not mention their method to count the number of dorsals around midbody, we supposed that this is the number of scales between lateral folds at midbody. Our examination of ZFMK 55110–55111 showed that the scales between lateral folds at midbody only range from 84–91 (131–136 scales in the original description). Therefore, this morphological character should be corrected as "scales around midbody" as it was mentioned for the holotype (132 scales around midbody).

In terms of priority, the formal description of *Gekko badenii* was published in Vestnik Zoologii on 15 April 1994, whereas the description of *G. ulikovskii* was published in the journal Salamandra on 15 May 1994. Therefore, based on the evidence mentioned above and according to the International Commission on Zoological Nomenclature (ICZN, 1999: Articles 23.1 and 23.3) *Gekko ulikovskii* Darevsky & Orlov, 1994 must be regarded as a junior synonym of *Gekko badenii* Szczerbak & Nekrasova, 1994.

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Fig. 3. Map showing the type localities of *Gekko badenii* (Tay Ninh Province) and *Gekko ulikovskii* (Kon Tum Province) in Vietnam.

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Table 1. Comparison of morphological characters of *G. badenii* Szczerbak & Nekrasova and *G. ulikovskii* Darevsky & Orlov based on the original descriptions and specimens examined ("–": character unobtainable from literature).

	Original description		**Specimens examined**	
	G. badenii	***G. ulikovskii***	***G. badenii***	***G. ulikovskii***
	n = 3	n = 11	n = 5	n = 2
Sex (M = male, F = female)	(2 M, 1 F)	(10 M, 1 F)	(3 M, 2 F, additional material)	(2 M, paratypes)
SVL	51.5–76.5	87–108	87–106	102.1–102.7
(mean ± SD)	(62.3 ± 0.7)	(101.1 ± 5.7)	(93.3 ± 7.6)	(102.4 ± 0.4)
Tail length (TaL)	72.0–93.5	80–112	82.8–107.8	95.8–99.6
(mean ± SD)	(82.7 ± 1.07)	(94.1 ± 11.1, n = 9)	(96.9 ± 12.3, n = 4)	(97.7 ± 2.7)
SVL/TaL	0.82	0.94–1.24	0.81–1.28	1.03–1.06
Snout length > orbit diameter	–	yes	yes	yes
Nostril in contact with rostral, supranasal, two postnasals, and first supralabial	yes	yes	yes	yes
Suture on upper part of rostral	present	present	present	present
Supralabials	12–15	11–14	12–14	11–14
Infralabials	13–14	9–13	11–12	12
Internasals	1–3	0–1	1	0–1
Interobitals	30–37	40–46	36–39	35–38
Gular scales	4–8	–	6–12	7–12
Number of gular scales in contact with infralabials	–	5	4–5	4–6
Scales around midbody	–	123–136	114–119	114–118
Number of dorsal tubercles	12	–	8–13	11–12
Ventral scales between axilla and groin	–	51	52–56	52–54
Ventral scales between latero-ventral folds	29–35	–	31–34	32–34
Subdigital lamellae under fourth toe	18–20	15–20	16–19	18
Precloacal pores	14–18	10–15	12–14	12
Enlarged subcaudals	–	56–83	60–68	59–63
Ground color of dorsum (in preservative)	brownish grey	dark grey	dark grey	dark grey
Light dorsal bands	4–8	8	6–8	7–8

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Fünfstück HJ, Ebert A, Weiss I (2010). Taschenlexikon der Vögel Deutschlands. 684 pp., Quelle & Meyer Verlag GmbH & Co., Wiebelsheim, ISBN 978-3-494-01471-5; 24,95 €.

For many birdwatchers buying a field guide is the first step into field ornithology. After identifying their first birds, prospective birdwatchers might wish to learn more about the species they just recognized. Reaching this goal is the aim of the work at hand which tries to inform in a compact format suitable for carrying in a rucksack about all bird species occurring in Germany. This lexicon is basically a summary of the „Kompendium der Vögel Mitteleuropas". It contains short chapters on taxonomy, origin of German and scientific names, occurrence, status, habitat, and breeding and feeding biology of all species found in Germany. These are complemented by short descriptions of appearance, voice, body masses and peculiarities. Each species is presented with a distribution map and photographs of almost always-good quality, completed by diagrams on phenology and moult. Even species that are rarely photographed in field guides of birds from Germany like Black Lark, Siberian Thrush or Northern Parula are depicted in this book. Generally, the proximity to the "Kompendium" provides reliability and timeliness of information. Nevertheless the lexicon is not error-free: Right in the beginning the explanatory distribution map is incorrect, as the light blue areas of migration periods and point occurrences are missing. The distribution area of the Green Willow Warbler has been displaced to Fennoscandia and Alaska, and superspecies are not always handled with care, e.g. for the Eastern black-eared Wheatear, Pied and Cyprus Pied Wheatear are missing as further members of the superspecies.

Furthermore, many topics are left out that can be found yet in the "Kompendium", for example information on population changes, behaviour, moult and conservation measures. A general preface and introductions to the families are nonexistent. Species are presented in alphabetical order of the German names, so that possibly longer lasting thumbing through the book could be necessary if for example looking up different species of a superspecies or genus, particularly since there is no register available. Searching for scientific names is hence impossible. Readers should be familiar with current taxonomic findings and changes of names, as species like Cory's Shearwater, Yellow Wagtail and Black-eared Wheatear are provided with new German names ("Sepiasturmtaucher", "Wiesenschafstelze", "Mauren- and Balkansteinschmätzer").

On the whole the lexicon is well suited for an entry into bird watching and can be recommended to everyone who is looking for a supplement to mere field guides. Wishing to seriously deal with field ornithology, though, requires purchasing additional books, such as the more costly but also more detailed three volumes of "Kompendium der Vögel Mitteleuropas".

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Zoologisches Forschungsmuseum Alexander Koenig, Bonn

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A new chameleon of the *Trioceros bitaeniatus* complex from Mt. Hanang, Tanzania, East Africa (Squamata: Chamaeleonidae)

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Abstract. A new species of *Trioceros* from the montane forests of Mount Hanang in Northwest Tanzania is described. The only known population of this species is found on Mt. Hanang in Tanzania around 2800 m a.s.l. This chameleon bears close morphological resemblance to *Trioceros sternfeldi* (Rand, 1963) from northern Tanzania. In order to infer phylogenetic relationships within the group, morphological and genetic data (mitochondrial 16S and 12S rRNA genes) were analysed. The new species could be compared with specimens of different populations of *Trioceros sternfeldi* (Mts. Meru, Kilimanjaro and Ngorongoro) and several other representatives of the family (*T. hoehnelii, T. ellioti, T. rudis rudis, T. bitaeniatus*). Results of maximum parsimony, maximum likelihood and Bayesian analyses consistently placed *Trioceros* n. sp. from Mt. Hanang as a single, independent terminal clade with high genetic divergences towards all other included members of the group.

Key words. Squamata, Chamaeleonidae, *Trioceros*, Africa, molecular phylogeny, biogeography

INTRODUCTION

Mt. Hanang represents one of the numerous ancient and isolated volcanic mountains which characterize the landscape of eastern Africa. In northern Tanzania Mts. Kilimanjaro, Meru, and the Ngorongoro Crater are three of the better known extinct volcanoes which are frequently visited by tourists and lie within some of Tanzania's most famous national parks. Several biologists identified these forested East African mountains as centers of endemism for chameleons of the "*rudis* group", a subgroup of the *Trioceros bitaeniatus* species complex (Rand 1963; Pilley 2000; Nečas et al. 2003). The *Trioceros bitaeniatus* complex comprises various taxa of small, hornless, ovoviviparous East African chameleons from the highland regions of eastern Africa, (Uganda, Kenya, Tanzania, southern Ethiopia and Sudan). All members of the group were placed into the separate subgenus *Trioceros* by Klaver & Böhme (1986) which was recently elevated to full generic rank by Tilbury & Tolley (2009). In contrast to other species of the *bitaeniatus* group, chameleons of the *rudis* subgroup are rather stocky animals with short, broad heads and heterogeneous scalation. They belong to a series isolated populations restricted to mountain forests ranging from the Ruwenzori in the north-west, south to the mountains east of Lake Malawi with outliers on Mt. Kilimanjaro, Mt. Meru and Ngorongoro in northern Tanzania. The Tanzanian forms of this subgroup were initially assigned to a *rudis*subspecies (*Chamaeleo rudis sternfeldi*) by Rand (1963), but this was long believed to be of rather specific than subspecific rank by several authors (e.g. Nečas et al. 2003). The independent taxonomic status of this form was subsequently demonstrated on the ground of morphological (Klaver & Böhme 1997; Krause 2006) and genetic data (Krause 2006).

The speciation of the *bitaeniatus* group as a whole seems closely related to the formation of the East African rift valleys when volcanism resulted in a separation of the ancestral populations. This can therefore be regarded as a major factor that gave rise to present day species (Pilley 2000; Wasser & Lovett 1993).

Three specimens of a curious chameleon from the *Trioceros bitaeniatus*- species complex were collected on Mt. Hanang at 2800 m altitude in March 2002, morphologically similar to *T. sternfeldi* (Rand, 1963) but with a very distinct colouration. This form is known only from the Mt. Hanang Catchment Forest Reserve (4° 25' to 4° 35' S and 35° 20' to 35° 25' E), situated about 4 km from the district capital Katesh and 70 km from the town Babati in the administrative region of Arusha in northern Tanzania (Figure 1).

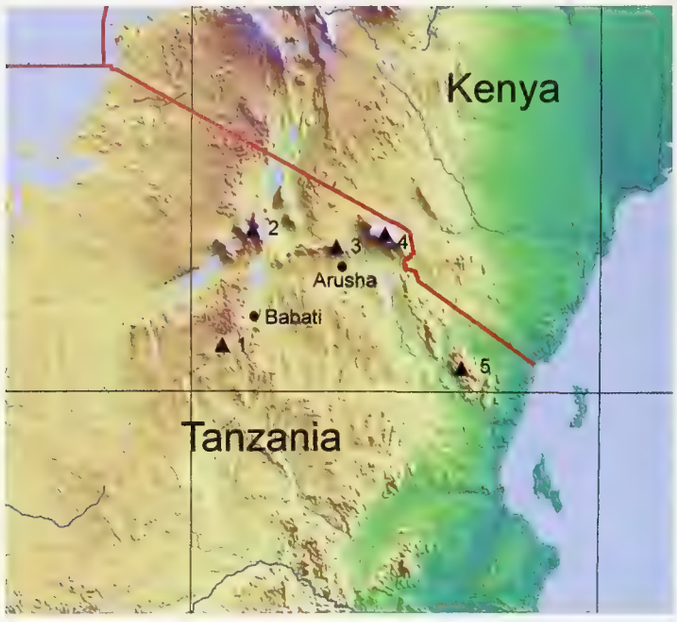

Fig. 1. Map of Tanzania with distribution of the discussed species. 1=Mt. Hanang: *T. hanangensis* n. sp.; 2=Ngorongoro: *T. sternfeldi*; 3=Mt. Meru: *T. sternfeldi;* 4= Mt. Kilimanjaro: *T. sternfeldi;* 5=Usambara Mts.: *T. sternfeldi.*

MATERIALS AND METHODS

All specimens were photographed *in situ* to record their natural coloration and habitus. Eversion of hemipenes in freshly dead specimens was done in the by injecting 70 % Alcohol into the organs (Glaw et al. 1999). The collected voucher specimens were deposited in the Zoologisches Forschungsmuseum Alexander Koenig in Bonn (ZFMK). Additional material was examined from the Zoologische Staatssammlung München (ZSM).

In order to test for morphological variation of the paratypes, chameleon body measurements were obtained with a digital caliper and evaluated with morphometric analyses methods (Krause 2006). Statistical analysis was performed using the GLM Multivariate procedure as implemented in SPSS 12 which provides analysis of variance for multiple dependent variables by one or more factor variables or covariates. In the present study the morphometric measurements (Krause 2006) excluding body length were chosen as dependent variables and the morphometric variable "snout-vent-length" was included as covariate to exclude the effect of body size on the other measured parameters. After an overall f-test has shown significance, post hoc tests (Scheffé) were applied to evaluate differences among the specific means. Probability values less than 0,05 were assumed to infer biological significance.

Molecular data could be obtained from tissue samples (muscle or liver, fresh or preserved in 98% ethanol) of the following taxa: *Trioceros* n. sp., (Mt. Hanang, Tanzania), *Trioceros rudis* (Uganda), *Trioceros sternfeldi* (Mt. Kilimanjaro, Mt. Meru, Tanzania). In order to analyse the phylogenetic relationships within the *bitaeniatus* group the following taxa were also included in the analysis: *T. ellioti*, *T. hoehnelii*, *T. bitaeniatus*, *T. narraoica*, *T. werneri*, *T. jacksonii*, *T. deremensis and T. johnstoni. Kinyongia uthmoelleri*, *Chamaeleo dilepis. Uromastyx acanthinura* and *Leiolepis belliana* were used as outgroups. All specimens included in this study are listed in Tab. 1 and sequences were submitted to GenBank (accession numbers AY927239-AY927276). DNA was extracted using the Chelex method (Walsh et al. 1991). In this study a 5% Chelex solution (2,5 mg Chelating Resin [Iminodiacetic Acid; Sigma Aldrich] in 50ml ddH_20) was used (Schmitz A 2003). Two mitochondrial genes which encode for the 16S und 12S subunits of the ribosomes (16S and 12S rRNA genes) where chosen for molecular analysis. Primers 16SA (light chain 5′- CGC CTG TTT ATC AAA AAC AT -3′) and 16SB (heavy chain 5′- CCG GTC TGA ACT CAG ATC ACG T) of Palumbi et al. 1991 were used to amplify a section of the 16S rRNA gene. The primers 12SA-L (light chain; 5' - AAA CTG GGA TTA GAT ACC CCA CTA T - 3') and 12SB-H (heavy chain; 5' - GAG GGT GAC GGG CGG TGT GT - 3') of Kocher et al. (1989) were used to amplify a section of the 12S rRNA gene. PCR cycling procedure for both gene-fragments was as follows: Initial denaturation step: 90s at 94°C, 33 cycles: denaturation: 45s at 94°C, primer anealing for 45s at 55°C, extension for 90s at 72°C.

Purification of the PCR products was conducted following standard methods using QIAquick PCR Purification Kit (Qiagen), sequencing reactions of the obtained amplified DNA including cycle sequencing (standard procedures) were conducted by MWG-Biotech and Max Planck Institut für Züchtungsforschung (MPI) in Cologne using ABI Prism DNA automatic sequencer.

Sequences were aligned using the computer program ClustalX (default parameters, Thompson et a. 1997). The alignment was subsequently adjusted manually using the computer program BioEdit (Hall 1999).

33 sequences (combined 16S and 12S rRNA genes) could be obtained, each comprising 861 bp, referring to the aligned sequences including gaps (16S: 479 bp; 12S: 382 bp). The alignment gaps were treated as missing character. The entire 16S+12S alignment was included in the analyses. As with two specimens (ZFMK 63223, 70752) only 12S sequences could be obtained, we conducted a separate analysis using the 12S dataset only.

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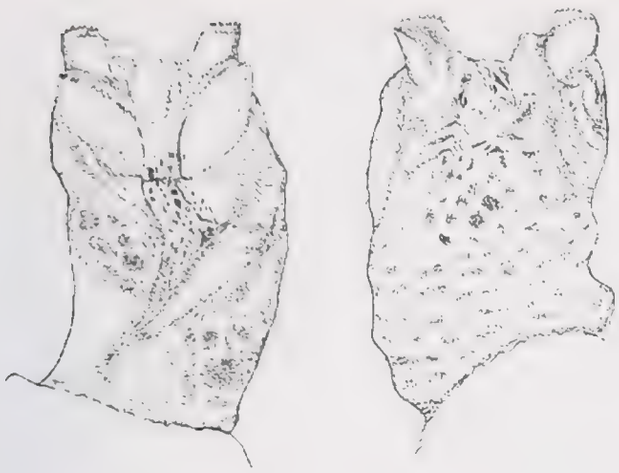

Fig. 2. Sulcal (left) and asulcal (right) view of the hemipenis of *Trioceros hanangensis* n. sp. from Mt. Hanang, Tanzania.

Data were analysed using maximum likelihood and parsimony optimality criteria in PAUP 4.0b10 (Swofford 2002), further we used Bayesian inference as implemented in MrBayes 3.1.1 (Ronquist & Huelsenbeck 2003). For maximum likelihood, a heuristic search was conducted with 10 replicates of random stepwise addition and tree bisection-reconnection (TBR) branch swapping. Relative branch support in phylogenetic analysis was evaluated with 100 bootstrap pseudoreplicates. Parsimony analyses used heuristic searches with 100 random additions of taxa and tree bisection-recombination branch swapping. When more than a single most parsimonious tree was found, a strict consensus tree was generated. Confidence in the nodes was assessed by 2000 bootstrap pseudoreplicates (Felsenstein 1985) with random addition of taxa. Only bootstrap supports of 70 % and higher were considered as reliable, as such values were found to indicate 95 % probability of correct topology (Hillis & Bull 1993). For Bayesian analyses a GTR+I+G model was chosen according to the optimal model and parameter-values based on the AIC criteria determined in MrModeltest 2.2 (Nylander 2004). Two MCMC analyses for 10^6 generations each were conducted. The topologies of the sampled trees were used to generate a strict consensus tree. Only clades with a posterior probability of 95% or greater where considered to be significantly supported.

RESULTS

Trioceros hanangensis n. sp.

Holotype. ZFMK 82369, adult male with everted hemipenis. Locality: Tanzania: Mt. Hanang Forest Reserve near the village Jorodom (4° 25' to 4° 35' S and 35° 20' to 35° 25' E) at 2800 m, collected by P. Krause, March 2002.

Paratypes. ZFMK 82368, subadult male, same data as the holotype; ZSM 111/1981/1- ZSM 111/1981/20 collected by L. Uthmoeller (1937) from the same locality as the holotype.

Diagnosis. A medium sized, stocky chameleon resembling a typical member of the *Trioceros bitaeniatus* complex (Rand 1963). The maximum total length is 138 mm; the tail comprises an average of 45 %, males with longer tails. Adult males and females have a similar snout-vent-length (SVL) the females being slightly larger. Body scalation is heterogeneous, with strongly enlarged denticulate scales in two distinct rows on the sides of the body. The gular crest is weak to medium, consisting of scales 1.5 times the length of their maximum width. A ventral crest is clearly visible in bigger specimens to almost indistinct in smaller ones. No rostral appendix is visible like in other members of the *bitaeniatus* complex (*Trioceros narraioca* Nečas, Modry & Slapeta, 2003; *Trioceros hoehnelii* Steindachner, 1891).

This chameleon bears a close morphological resemblance to *Trioceros sternfeldi* from northern Tanzania (Mts. Kilimanjaro, Meru and Ngorongoro Crater) but shows a distinct colour pattern, which differs remarkably from *T. sternfeldi* (Sternfeld 1912a, Figures 3, 5, 6). Further, it possesses scattered melanophores on the sulcus of the hemipenis which are unique as compared to *T. sternfeldi*.

Despite a close genetic relationship with *T. ellioti,* the new form can clearly be distinguished by absence of the distinct longitudinal groves on the gular pouch, a more heterogeneous scalation and a stouter body as compared with *T. ellioti,* which is rather slim (Günther 1895; Spawls et al. 2002).

The only known population of this species is found on Mt. Hanang above 2800 m in montane bushland.

Description of holotype. Head short and broad, distance from tip of snout to end of parietal crest less than twice greatest width between the temporal ridges. Parietal crest not swollen posteriorly, being almost straight in profile. No rostral projection at the point of fusion of canthi rostrales. Occipital flaps absent. Ventral crest moderately developed, composed of cone-shaped, subequal scales, longest on throat, about 3/4 of eye diameter. Throat homogenously covered with small scales, no indication of longitudinal grooves. Head length (from tip of snout to posterior margin of casque) 21 mm. Height of casque (from angle of mouth to top of casque) 16 mm, slightly less than length of mandible (20 mm). Caudal side of casque homogenously covered with fine granular scales. Parietal crest consists of 15 enlarged elongate scales. Two other diagonal (paraparietal) crests visible on each side of

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Fig. 3. Holotype of *Trioceros hanangensis* n. sp. (male, ZFMK 82369) from Mt. Hanang, in life.

head, consisting of 4 enlarged tubercular scales. These originate in the immediate vicinity of the parietal crest and run rostrolaterally towards the orbit. Lateral crests composed of 4 enlarged, prominent pointed scales, extending to the supraorbital crest (11 pointed scales) and to canthi rostrales (5 scales).

Body rather stout. Dorsal crest well developed, composed of scales in groups of three anteriorly and four posteriorly. Increasing posteriorly in size within the group, giving the back a serrate appearance. Dorsal crest extends to the tail and becomes indistinct within its terminal third. The first scales of the series of three just behind the head are longest, reaching 1.7–2 mm length. Ventral crest moderate to weak, best developed on the throat; posteriorly scales are shorter but still visible up to posterior belly.

Scalation heterogeneous. Sides of body, tail and upper surfaces of limbs covered with irregularly sized, convex, small scales interspersed with larger convex scales. Largest of these form a narrow row running from neck just behind temporal crests to tail. A second row of slightly smaller scales runs from shoulder to hind leg. This row is much less distinct and more irregular. Vent, inner side

Fig. 4. *Trioceros hanangensis* n. sp. (subadult male, ZFMK 82368) from Mt. Hanang.

Fig. 5. *Trioceros sternfeldi* (male) Ngorongoro Crater.

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Fig. 6. *Trioceros sternfeldi* (male) Mt. Kilimanjaro.

of legs, soles and underside of the tail almost homogeneously scaled. No tarsal spurs.

Hemipenis. Smooth margined calyces cover the asulcal side of the hemipenis, extending as far as the sulcal lips. Apical tip characterised by two pairs of finely serrate rotulae of roughly semicircular shape, positioned towards the sulcal side and extending around lateral side of hemipenis. Scattered melanophores could be observed in the sulcus (Figure 2).

Colouration and pattern. Vivid green with lateral yellow bar following the row of enlarged scales running from neck to the base of tail. Head light blue except gular region. Eyeballs bright blue to turquoise.

Variation of the paratypes. Analysis of morphometric variation between male and female specimens of *Trioceros* n. sp. from Mt. Hanang resulted in males having significantly broader heads than females (x = 13,09 mm vs. x = 12,59 mm; p = 0,030) and a tendency to increased rugosity in adult males. There is no apparent statistical difference in snout-vent-length (SVL) comparing both sexes. (males: SVL = 72,30 mm, N = 9 / females: SVL = 75,52 mm, N = 14). No significant differences in relative tail length (TL) between sexes could be observed (males: TL = 66,22 mm / females: TL = 62,71 mm).

Distribution. Only known from Mt. Hanang Catchment Forest Reserve (4° 25' to 4° 35' S and 35° 20' to 35° 25' E) situated about 4 km from the district capital Katesh and 70 km from the town Babati in the administrative region of Arusha. The new species is named after the type-locality Mount Hanang.

Ecological remarks and habitat preference.: *T. hanangensis* n. sp. was found in upland moorland at 2800 m on the moister north-eastern side of Mt. Hanang. Despite a prevaling semi-arid climate with 750–1500 mm annual rainfall, a pronounced mist effect on the eastern and north-eastern slopes is leading to a maximum of 2000 mm precipitation per year at the higher regions of the mountain. The sampled specimens where observed during daytime in bushy highland vegetation (with *Hypericum* sp., *Myrsine africana*, *Protea* sp.) near the source of the river Himit, roosting on twigs at a height ranging from 100–150 cm from the ground.

Phylogenetic affinities. In order to infer the phylogenetic relationships between the different members of the *bitaeniatus* group on the basis of molecular data maximum parsimony (MP), maximum likelihood (ML) and Bayesian analyses (PP) were conducted. Maximum likelihood analysis was conducted with a reduced dataset, due to computational constraints. Sequences obtained from the combined 16S+12S rRNA mitochondrial genes were analysed together with gene-fragments of *Trioceros sternfeldi, T. rudis*, *T. ellioti*, *T. hoehnelii*, *T. bitaeniatus*, *T. narraoica*, *T. werneri*, *T. jacksonii*, *T. deremensis* and *T. johnstoni*. The two included specimens of *T. hanangensis* n. sp. were found in a well supported clade in the MP and Bayesian trees (MP: 99; PP: 1.00), separating them

Fig. 7. Mt. Hanang from Katesh, SSW side of the mountain.

Fig. 8. Type locality of *Trioceros* at 2800 m altitude.

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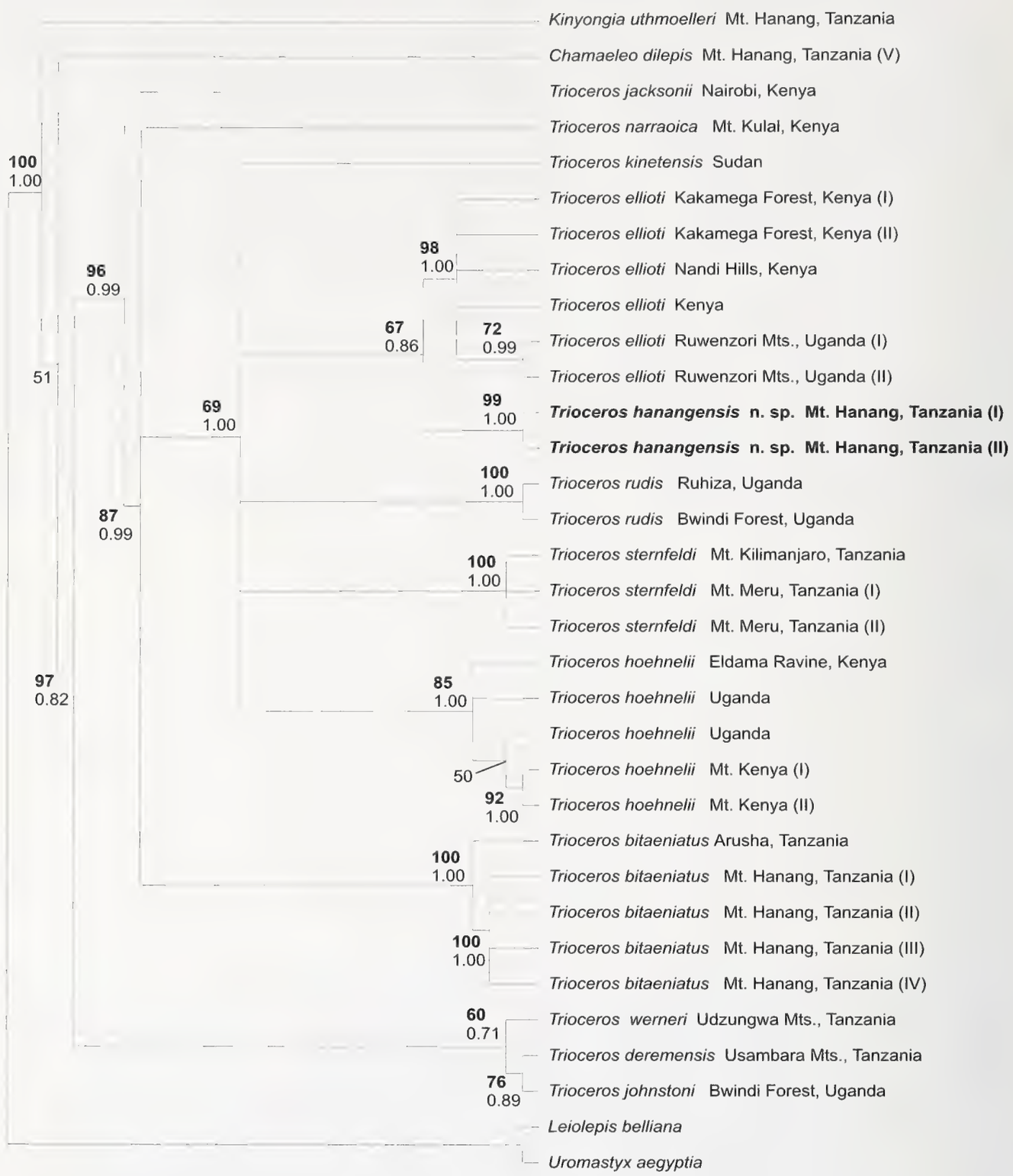

Fig. 9. Strict consensus parsimony tree derived from the combined fragment of the mitochondrial 12S and 16S rRNA genes. Parsimony bootstrap values are given above the nodes (bold), lower values are posterior probabilities produced by Bayesian inference. Nodes with less than 50 % bootstrap support are not labelled.

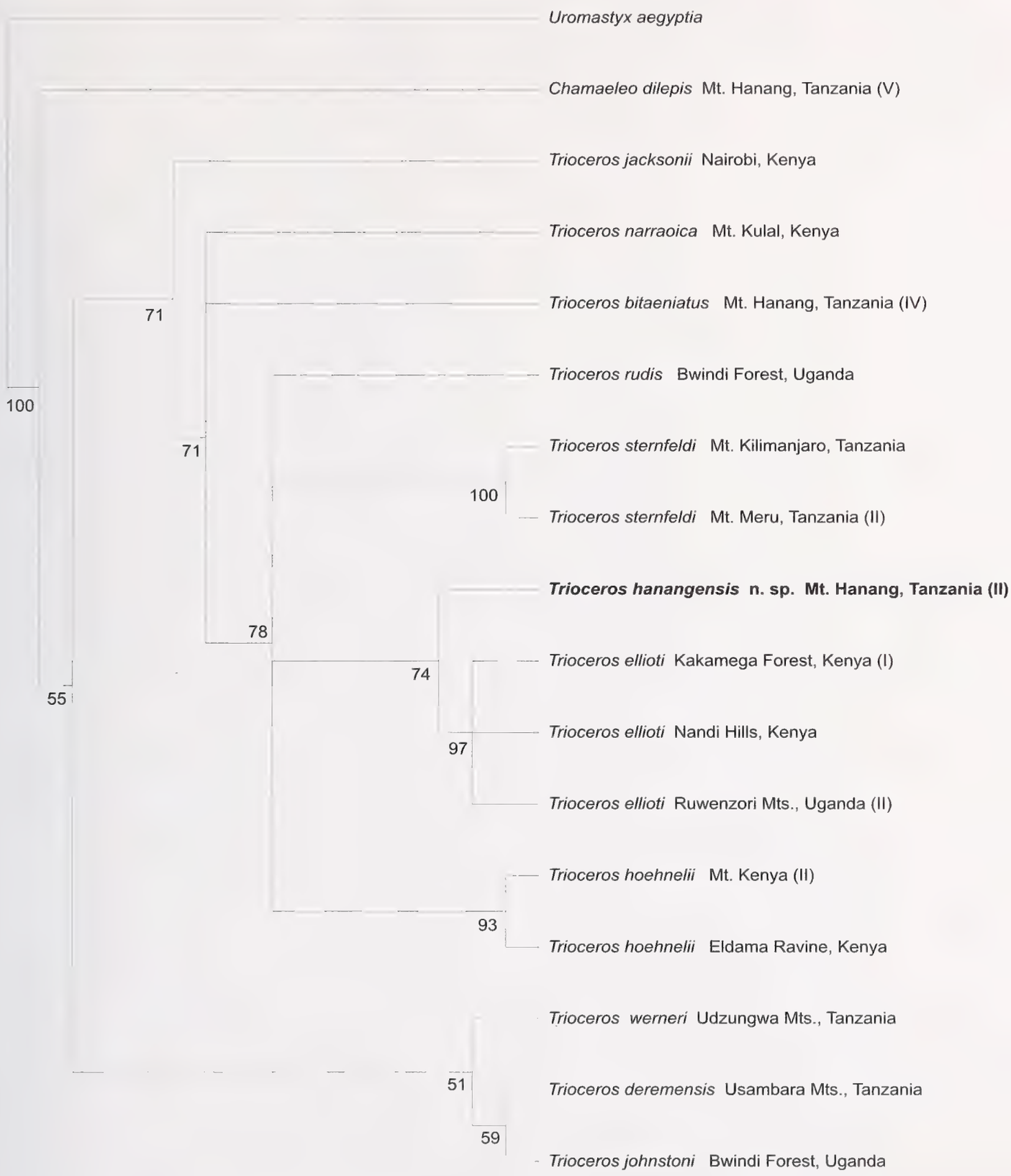

Fig. 10. ML tree derived from the combined fragment of the mitochondrial 12S and 16S rRNA genes. Bootstrap values are given above the nodes, nodes with less than 50 % bootstrap support are not labelled.

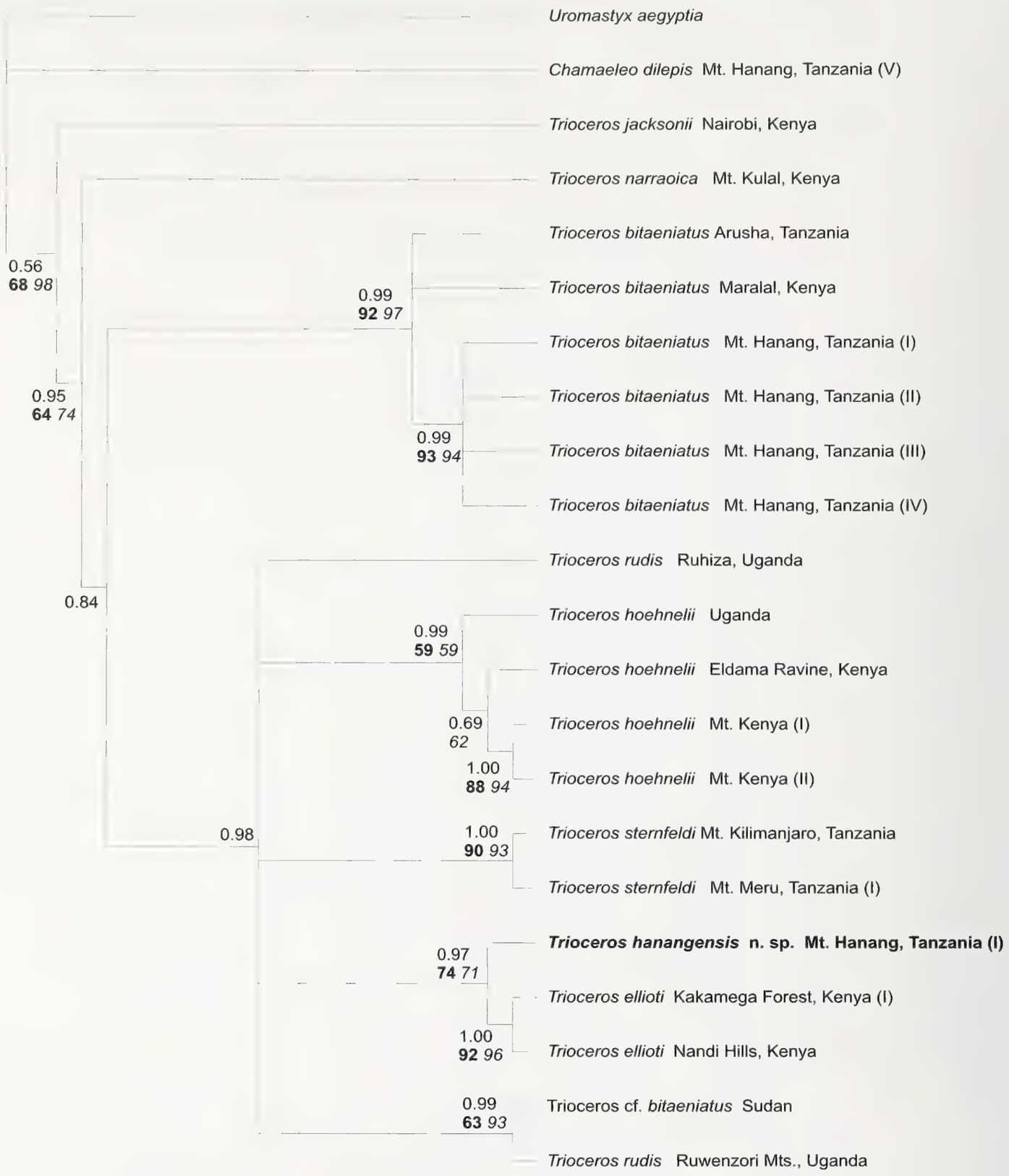

Fig. 11. Consensus tree derived from Bayesian inference using the mitochondrial 12S gene. Posterior probabilities are given above, ML bootstrap values (bold) and MP bootstrap values (inverse) below. Nodes with less than 50 % bootstrap support are not labelled.

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Table 1. Specimens included in this study.

Species	Locality	Collection number	Accession number 16S/12S	
Kinyongia uthmoelleri	Mt. Hanang, Tanzania	ZFMK 82191	DQ397231	DQ397245
Chamaeleo dilepis	Mt. Hanang, Tanzania (V)	ZFMK 82361	AY927263	AY927244
Trioceros ellioti	Kakamega Forest, Kenya (I)	ZFMK 82058	DQ397278	DQ397258
Trioceros ellioti	Kakamega Forest, Kenya (II)	ZFMK 30835	DQ397279	DQ397259
Trioceros ellioti	Nandi Hills, Kenya	ZFMK 82057	DQ397225	DQ397239
Trioceros ellioti	Kenya	ZFMK 70818	DQ397280	DQ397260
Trioceros ellioti	Ruwenzori Mts., Uganda (I)	ZFMK 63287	DQ397281	DQ397256
Trioceros ellioti	Ruwenzori Mts., Uganda (II)	ZFMK 63227	DQ397282	DQ397257
Trioceros hanangensis s.p. nov	Mt. Hanang, Tanzania (I)	ZFMK 82368	DQ397283	DQ397254
Trioceros hanangensis s.p. nov	Mt. Hanang, Tanzania (II)	ZFMK 82369	DQ397284	DQ397255
Trioceros rudis	Ruhiza, Uganda	CAS 201781	DQ397223	DQ397223
Trioceros rudis	Bwindi Forest, Uganda	CAS 201711	DQ397285	DQ397252
Trioceros rudis	Uganda	ZFMK63223	-	DQ397277
Trioceros kinetensis	S-Sudan	ZFMK 29714	DQ397286	DQ397253
Trioceros sternfeldi	Mt. Kilimanjaro, Tanzania	ZFMK 68629	DQ397287	DQ397261
Trioceros sternfeldi	Mt. Meru, Tanzania (I)	T068 (prov. ID)	DQ397288	DQ397263
Trioceros sternfeldi	Mt. Meru, Tanzania (II)	ZFMK 82250	DQ397289	DQ397262
Trioceros hoehnelii	Mt. Kenya (I)	ZFMK 70678	DQ397290	DQ397265
Trioceros hoehnelii	Uganda	voucher not collected	DQ397291	DQ397266
Trioceros hoehnelii	Mt. Kenya (II)	ZFMK 66578	DQ397292	DQ397264
Trioceros hoehnelii	Eldama Ravine, Kenya	ZFMK 82088	DQ397224	DQ397238
Trioceros hoehnelii	Uganda	voucher not collected	DQ397293	DQ397267
Trioceros bitaeniatus	Mt. Hanang, Tanzania (I)	ZFMK 74949	DQ397222	DQ397237
Trioceros bitaeniatus	Mt. Hanang, Tanzania (II)	ZFMK 74952	DQ397294	DQ397269
Trioceros bitaeniatus	Mt. Hanang, Tanzania (III)	ZFMK 82365	DQ397295	DQ397270
Trioceros bitaeniatus	Mt. Hanang, Tanzania (IV)	ZFMK 82366	DQ397296	DQ397271
Trioceros bitaeniatus	Arusha, Tanzania	ZFMK 82251	DQ397297	DQ397272
Trioceros bitaeniatus	Maralal, Kenya	ZFMK 70752	-	DQ397276
Trioceros narraoica	Mt. Kulal, Kenya	ZFMK 73958	DQ397298	DQ397268
Trioceros jacksonii	Nairobi, Kenya	CAS 199070	DQ397226	DQ397240
Trioceros werneri	Udzungwa Mts., Tanzania	ZFMK 70452	DQ397299	DQ397274
Trioceros deremensis	East Usambara Mts., Tanzania	CAS 168888	DQ397300	DQ397273
Trioceros johnstoni	Bwindi Forest, Uganda	CAS 201597	DQ397301	DQ397275
Leiolepis belliana	Egypt	GenBank	AB031986	AB031969
Uromastyx aegyptia	Thailand	GenBank	AB031994	AB031977

from all other included taxa. In the tree resulting from the maximum likelihood analysis, the single included specimen of *T. hanangensis* n. sp. clustered together with *T. ellioti* (ML: 74). Genetic distances to all other included taxa of the *bitaeniatus* group were relatively high (2,2–4 %) and were within the range which could be found between well defined species. This confirms the independent specific status of *Trioceros hanangensis* n. sp.

Phylogenetic inference of the combined 16S+12S rRNA dataset revealed a sistergroup relationship with *T. ellioti*, which was weakly to moderately supported with all methods (MP: 67; PP: 0.86; ML: 74). A genetic distance of 2,05-2,18 % could be observed between *Trioceros hanangensis* n. sp and the included specimens of *T. ellioti*. Using only the 12S fragment for phylogenetic inference, a much higher support for this sistergroup relationship could be observed (MP: 89; PP: 0.99; ML: 81). Nevertheless, the relationships of *T. hanangensis* n. sp. towards the other taxa of the *bitaeniatus* group, especially towards *T. sternfeldi* could not be finer resolved with the available limited genetic dataset, resulting in a large polytomy in all trees.

Conservation status. The forested area on Mt. Hanang is classified as a Catchment Forest Reserve covering approx. 40 km^2 which is relatively small compared to other reserves in Tanzania. The genuine forest of Mt. Hanang has been drawn back to the very base of the mountain and is under increasing threat by illegal logging, fires and drought. Due to the small size of the reserve, even minor disturbances are likely to affect the habitat of forest dependant species like *T. hanangensis* n. sp. Along with the well-known mountains in northern Tanzania like Meru, Kilimanjaro, Ngorongoro and the Eastern Arc, Mt. Hanang is a further example of a remnant mountain forest with quite unique climatic and ecological conditions. For this reason the protection and management of the remaining forests on Mt. Hanang should receive urgent priority.

DISCUSSION

Trioceros hanangensis n. sp. is a member of a species complex which is closely associated with the forest covering many of the East African mountains. These

chameleons represent a subgroup of the *bitaeniatus*-group (the "*rudis* group"sensu Rand 1963). In contrast to other species within the *bitaeniatus* group, populations of the *rudis* group are restricted to mountain forests with widely disjunct distribution, each population bearing specific morphological peculiarities distinguishing it from the others as first observed by Rand (1963).

Like the *bitaeniatus* group as a whole, the different forms of the *rudis* group can most easily be understood as relics of a period equating with the last pluvial period of the Pleistocene when the rainfall in East Africa was higher and the forest was much more extensive than today. Drier periods following the pluvial maxima resulted in a retreat of the forests from the lower elevations to their present positions on the higher mountains. As a consequence the chameleon populations living in these forests (Wasser & Lovett 1993) were also fragmented. Different selection pressures formed the various taxa (*T. schubotzi*, *T. sternfeldi* or *T. hanangensis* n. sp.) which are today restricted to relatively small areas or certain types of habitat. In contrast to the mountains of the Eastern Arc, most volcanoes in northern Tanzania are relatively young and result from volcanic activity persisting from the Oligocene (37 myr ago) to the Quaternary. As a consequence, the origin of the different *rudis*-forms cannot lie very far in the past which makes it a rewarding subject for the investigation of beginning speciation processes.

Despite a morphological similarity with *Trioceros sternfeldi* (Mts. Meru, Ngorongoro and Kilimanjaro) *T. hanangensis* n. sp. can be regarded as valid species, chief indicators being a distinct colour-pattern, presence of scattered melanophores in the sulcus of the hemipenis (not present in *T. sternfeldi*) and the high degree of genetic differentiation towards *T. sternfeldi* and the other members of the group. Molecular analysis of the combined 16S+12S dataset shows a genetic differentiation between 2,2–4 %, which is clearly above the intraspecific level and confirms the independent specific status of *T. hanangensis* n. sp.

A weakly supported sister-group relationship towards *T. ellioti* is indicated by all the given trees (MP: 67; PP: 0.86; ML: 74). In contrast to *T. ellioti T. hanangensis* n. sp. does not possess the distinct longitudinal groves on the gular pouch as present in *T. ellioti*, it has a more heterogeneous scalation and a stouter body than *T. ellioti* (Günther 1895; Spawls et al. 2002). Further, *T. ellioti* has a wide distribution ranging from western Kenya, the northern shore of Lake Victoria in Uganda, western Uganda, Rwanda and Burundi and occurs in open bushland and grassland.

Limited by the available genetic dataset, phylogenetic relationships towards the other members of the *bitaeniatus* group could not be sufficiently resolved . Phylogenetic affinities of *T. hanangensis* n. sp. and *T. sternfeldi* can only be assumed by means of morphological data: specimens of *T. sternfeldi* from Mt. Kilimanjaro have dark eyeballs, in contrast to *T. sternfeldi* from Ngorongoro and *T. hanangensis* n. sp. which both have light blue eyeballs and are more alike in general colouration. The parietal knob observed by Rand (1963) associated with specimens from Mt. Meru and Mt. Kilimanjaro could not be observed in specimens from Mt. Hanang respectively Ngorongoro. These observations support the assumption that *T. hanangensis* n. sp. is more closely related to *T. sternfeldi* from Ngorongoro than with the *sternfeldi*-populations from Meru and Kilimanjaro. The geography of the region would have allowed geneflow between the populations of Hanang and Ngorongoro in the past: particularly to the north-west of Mt. Hanang a continous forest could have existed during moister periods linking the habitat of *T. hanangensis* n. sp. with the Nou- and Marang forests and further north with Oldeani (3188 m) and Ngorongoro (3000 m). Today, a dry and hot valley separates the mountain from the rift-wall and forms an impenetrable barrier for forest dependent species.

A similar observation could be made with *Kinyongia uthmoelleri*, an endemic of the highlands of Hanang and Ngorongoro: the two populations show closest morphological and genetic relationships (Krause 2006) which as well supports the above presumed close relationship between *T. hanangensis* n. sp. and *T. sternfeldi* from Ngorongoro.

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Reptiles from southern Benin, West Africa, with the description of a new *Hemidactylus* (Gekkonidae), and a country-wide checklist

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Abstract. We report on a collection of reptiles made in southern Benin, mostly in the vicinity of Lama Forest, a relict rain forest surrounded by savannah habitats within the the so-called Dahomey gap. 48 species (3 chelonian, 20 saurian and 25 ophidian species were encountered) are listed with the respective voucher material and commented in respect to taxonomic or ecological information. Five lizard species (*Agama sylvanus*, *Hemidactylus ansorgei*, *H. lamaensis* n. sp., *Holaspis guentheri*, *Varanus ornatus*) and two snake species (*Natriciteres variegata*, *Amblyodipsas unicolur*) are new for the fauna of Benin, the second *Hemidactylus* species being even new to science. Some other species are reported from Benin for only the second time.

This commented list of species collected from southern Benin is followed by a general country-wide checklist, which is based on literature data and also some unpublished records from northern Benin, among them the remarkable rediscovery of *Agama gracilimembris*, 9 decades after its original description from this country.

Key words. Reptilia: Chelonia, Crocodylia, Squamata; Benin, West Africa, new country records; *Hemidactylus lamaensis* n. sp.; country-wide checklist

INTRODUCTION

Herpetologically, Benin is among the most insufficiently known countries in Africa. Bordered by Togo in the west, Burkina Faso and Niger in the north, and Nigeria in the east, Benin is best-known by its old name Dahomey, because of the denomination of the huge savannah gap that separates the Upper Guinean rain forests from those of the Lower Guinean-Congolian forest block as Dahomey Gap.

Among the first authors who dealt especially with Benin reptile material within the framwework of West African herpetology is Chabanaud (1916, 1917). During his curatorship in the Museum of Natural History in Paris he published on acquisitions from this former part of French West Africa by the following collectors: Dr. G. Bouet, Healt Inspector of French West Africa ("Dahomey", 1910–1913), Dr. Brot ("Haut-Dahomey", 1908), Mr. A. Chevalier ("Dahomey", 1909–1910), Mr. de Gironcourt ("Haut-Dahomey", 1910), Mr. Gruvel ("Dahomey", 1913), Mr. Primot ("Dahomey", 1914), and Mr. Waterlot ("Dahomey", 1914). The next important step in the exploration of this country was the mission to Togo and Dahomey carried out by A. Villiers in 1950 (see Villiers 1951, Loveridge 1952) which covered all important biotopes of these two countries. In 1999, Sinsin & Bergmans (1999) edited a book on rodents and snakes in Benin under mostly agricultural aspects. The table on the West African snake fauna including Benin provided for this book by Meirte is not considered here because it marks many species in this table as occurring in Benin without any reference to the source on which the information is based; on the other hand, several species are marked as questionably or not at all occurring in Benin (e.g. *Scaphiophis albopunctatus*, *Telescopus variegatus*, *Toxicodryas blandingii*, *Psammophis* cf. *sibilans*, *P. phillipsi*: Meirte 1999) although they have been documented by museum voucher specimens in the earlier works cited above (see also the country checklist at the end of this paper).

Where the savannah reaches the southern coast of West Africa the Dahomey gap stretches from roughly between Accra (Ghana) to Lagos (Nigeria), thus making Benin a seemingly pure savannah country. However, some forest

remnants such as Forêt de Dan, Forêt de Lama and Forêt de Lokoli are still present in the southern part of Benin. The senior author of this paper (KU) had the opportunity to work on a herpetological survey of the most important of these relict forest remnants, viz. Forêt de Lama. This work took place within the framework of a project ("Biolama") of the University of Basel, Switzerland, guided by Prof. Dr. Peter Nagel (see Lachat et al. 2006). The herpetological voucher material of this survey, which included also specimens obtained from neighbouring forest and savannah areas (Ullenbruch 2003) is deposited in the Zoologisches Forschungsmuseum Alexander Koenig (ZFMK), Bonn, Germany. The amphibian part of this collection contained some important first country records of rain forest species (e.g. *Ptychadena aequiplicata*) and has already been included in a recent paper by Rödel et al. (2007). Amphibians collected by O. Grell in the Pendjari National Park, northern Benin (Grell 2003) have been incorporated in the study by Nago et al. (2006). The reptilian records of this last-mentioned survey, mostly documented by photographs, are included here only in the country-wide checklist at the end of this paper. The faunistic and ecological information on the reptiles of southern Benin (mission K. Ullenbruch) is presented here in a systematically arranged, commented species list. This list further contains some voucher material collected and donated to ZFMK by Dr. Werner Schröder, Göttingen, in 1984.

The commented regional species list which contains also the description of one new species, is supplemented by a general, country-wide checklist that tries to summarize all literature data for Benin as a whole.

REPTILES FROM LAMA FOREST, SOUTHERN BENIN, AND NEIGHBOURING AREAS

Lama Forest or Forêt de Lama is situated within a depression bearing the same name, 80 km north of Benin's capital Cotonou (Figure 1). It is bordered in the north by the plateau of Abomey and in the south by the plateau of Allada. Lama Forest comprises a total area of 16.250 ha of "forêt classée", 9.750 ha of which belong to the Département Atlantique (Sous-préfecture Toffo) and 6.500 ha belonging to the Department Zou (Sous-préfecture Zogbodomé) (Emrich et al. 1999). The center of this protected area – the protectional status exists since 1947 – is formed by the Noyeau Central (4.777 ha) which is composed of primary forest (1.937 ha), degraded forest (1.388 ha) and of teak plantations and fallow grounds (together 1.452 ha) (Figure 2). The Noyeau Central is surrounded by ca 9.000 ha of forestry plantations. In earlier times, the primary forest covered the whole Lama depression which stretches over the south Benin in a west-east direction. Until 1946, large areas of natural forest were already destroyed, and only 11.000 ha remained. Since the 1960ies reforestations are taking place which favoured, however, mainly teak plantations. The natural vegetation has been protected only from 1988 onwards (Emrich et al. 1999). Mean annual precipitation is 1100 mm with two peaks (big and small rainy seasons) in March to June and September to October respectively. The annual mean temperature lies between 25–29°C. The eastern part of the Lama depression is crossed – in north-south direction – by the Ouémé River valley. Close to Lama Forest, there are only few smaller creeks. During the rainy seasons, however, large parts of the area are changed into overflooded marshlands. Due to these repeated inondations and stagnant watres, there are only six dominant tree species in Llama Forest, viz. *Dialium guineense*, *Diospyros mespiliformis*, *Albizia zygia*, *Afzelia africana*, *Khaja senegalensis*, and *Anogeissus leiocarpus*. The Noyeau Central consists mainly of a mixture of relicts of a semideciduous forest which floristically approaches the "Forêt de Samba"

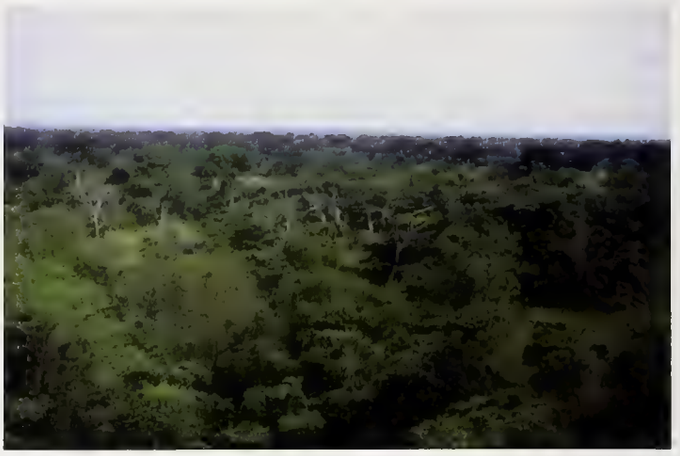

Fig. 1. View on Forêt de Lama, South Benin. Photo: K. Ullenbruch

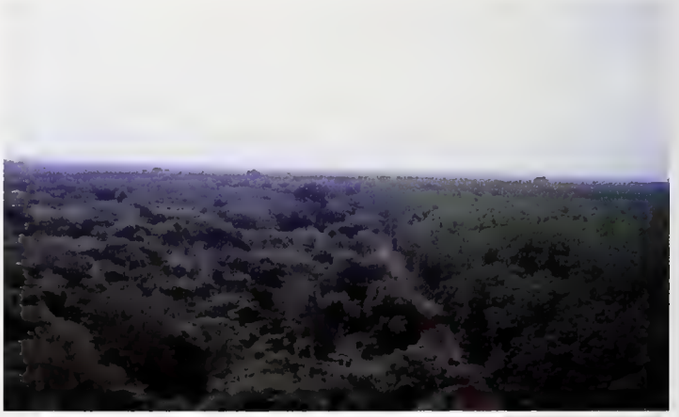

Fig. 2. Primary forest of Forêt de Lama (Noyeau central) (left) with bordering teak plantations (right) Photo: K. Ullenbruch

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Fig. 3. Landscape round the village of Didja, southern Benin. Photo: K. Ullenbruch

type (Mondjkannagni 1969) and of secondary forest in various developmental stages. Within this dynamic system, the South American fast-growing asteracean neophyte *Chromolaema odarata* is commonly found along small roads and paths and at the forest edges. In smaller plantations, next to the larger ones with teak, trees such as *Gmelina arborea*, fraké (*Terminalia superba*), samba wood (*Triplochiton skleroxylon*) and, especially in the Toffo sector, the fire-resistent *Cassia siamea* are cultivated (Specht 2002).

The remaining collecting sites in southern Benin were:

- Didja village, situated ca. 25 km NW of Bohicon and largely surrounded by an agriculturally formed landscape. The area north of Didja is characterised by bush and tree savannas (Figure 3).
- Dan Forest or Forêt de Dan is situated ca. 15 km NE of Didja and is regularly visited by hunters from Didja.

Fig. 4. Gallery forests at the Zou River, southern Benin. Photo: K. Ullenbruch

- Za-Kpota, 18 km NE of Bohicon, is likewise largely surrounded by an agricultural area, replaced in the northwest by large tree savannas. 7 km N of Za-Kpota, the Zou River is running, being accompanied on its banks by a small strip of dense and degraded gallery forest which belongs to the hunting grounds of the villagers (Figure 4).
- Lokoli Forest or Forêt de Lokoli, a 500 ha large forest on the Hounto River, ca. 100 km N of Cotonou. Numerous sidearms of the Hounto River run through Lokoli Forest so that it is penetrable only by boat (Figure 5). For further details, in the context of an amphibian survey, see Rödel et al. (2007).

Fig. 5. Flooded forest of Forêt de Lokoli. Photo K. Ullenbruch

Finally, some reptiles were collected also in Cotonou and Bohicon, on house walls and in gardens, and markets were visited to inspect the reptile species offered. Most of the reptiles were collected by UK by visual encounter and focal sampling. Moreover, specimens were brought by the locals, particularly by two snake hunters from Didja and Za-Kpota respectively who even received an alcohol-filled bucket in order to keep interesting snake finds for some days. The Swiss zoologists of the Biolama project provided us with few, but very important voucher specimens (e.g. *Hemidactylus* sp.n., *Holaspis guentheri*) taken in trunk eclectortraps used for the entomological survey.

The survey of the reptile fauna of Lama Forest, South Benin, and the neighbouring localities mentioned above revealed the existence of 48 species (2 turtle, 1 tortoise, 20 lizard, and 25 snake species) which are listed and discussed in the following.

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ANNOTATED LIST OF SOUTHERN BENINIAN REPTILES

Testudinidae

Kinixys belliana nogueyi (Lataste, 1886)

Material examined. photographic voucher only (Figure 6).

Remarks. This specimen was brought to KU by a local hunter. It was taken near Bohicon and was released after photographic documentation.

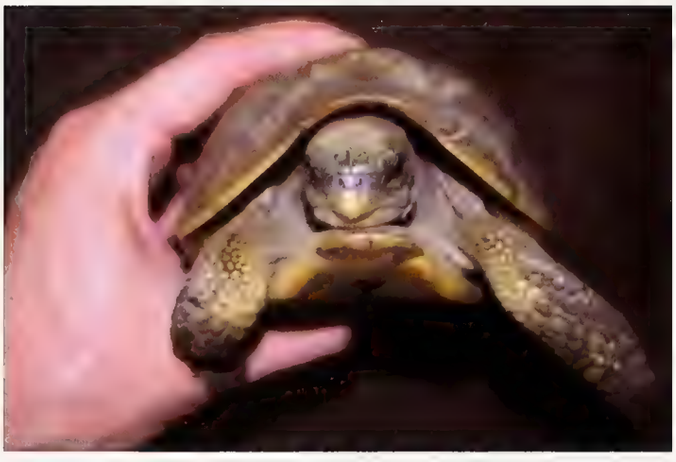

Fig. 6. *Kinixys belliana nogueyi* from near Bohicon, southern Benin. Photo: K. Ullenbruch

Pelomedusidae

Pelomedusa subrufa (Lacépède, 1788)

Material examined. photographic voucher only (Figure 7).

Remarks. Specimen taken by local hunter near Bohicon, photographed and afterwards released.

Pelusios castaneus (Schweigger, 1812)

Material examined. photographic voucher only (Figure 8).

Remarks. Specimen taken by local hunter near Bohicon, photographed and afterwards released.

Agamidae

Agama aff. *agama* (Linnaeus, 1758)

Material examined. ZFMK 42019-024 (3 males, 3 females), Godomey near Cotonou, coll. by W. Schröder, August/September 1984; ZFMK 77061-062, Bohicon, ZFMK 77063-064, Cotonou, all coll. by K. Ullenbruch, May/June 2002.

Fig. 7. *Pelomedusa subrufa* from near Bohicon, southern Benin. Photo: K. Ullenbruch

Remarks. This common and widespread species was observed in all habitats including human settlements where vertical structures such as tree trunks and/or house walls were preferred. It was, however, never seen in the closed forest.

Fig. 8. *Pelusios castaneus* from near Bohicon, southern Benin. Photo: K. Ullenbruch

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Agama sylvanus Macdonald, 1981

Material examined. ZFMK 77065, Forêt de Lama (Noyeau Central), coll. by K. Ullenbruch, 6 June 2002.

Remarks. The single juvenile specimen was obtained in an arthropod trap fixed at the trunk of a dead tree (trunk eclector) in dense primary forest. A second juvenile was observed at about 5 m height and escaped upwards. During the three months of the survey, no further specimen of this agama was seen which argues for either a secretive lifestyle or a general rarity, at least in this season of the year.

The morphological characters of ZFMK 77065 lie within the range of variation of *A. sylvanus* which was described by Macdonald (1981) from Ghana. Joger (1990) recorded the species also from Cameroon (as *A. paragama sylvanus*). The disjunction between these two countries is partially bridged by our specimen which represents the first country record for Benin.

Chamaeleonidae

Chamaeleo gracilis Hallowell, 1842

Material examined. ZFMK 77056-057, environs of Didja, coll. by a native hunter, 10 and 30 May 2002 resp.

Remarks. The two males were obtained from a native hunter on the market of Abomey who certified their origin as close to Didja. *C. gracilis* is widespread in the Sudan and Guinea savannah belt south of the Sahara. The rudimentary occipital flaps distinguish it from the following, only recently described species.

Chamaeleo necasi Ullenbruch, Krause & Böhme, 2007

Material examined. ZFMK 77058, male, Za-Kpota, ZFMK 77059-060, 2 females, Houégbo, all coll. by K. Ullenbruch, May/June 2002.

Remarks. The three specimens form part of the type series of this species which is otherwise known only from Togo (Ullenbruch et al. 2007). The Togolese localities (Kpalimé, Missaboué) as well as the two Benin localities are situated close to relict forest patches within the arid Dahomey gap. Za-Kpota is an agriculturally shaped site not far from the river Zou which has some degraded gallery forest vegetation, while Houégbo is not far from Lama Forest.

C. necasi belongs to the *C. dilepis* group and differs from the south Nigerian populations of the closely related *C. quilensis* mainly by hemipenial characters (see Ullenbruch et al. 2007).

Chamaeleo senegalensis Daudin, 1802

Material examined. ZFMK 42025 (male), Bohicon, coll. by W. Schröder, August/September 1984; ZFMK 77052-055, environs of Didja, coll. by a native hunter, 10 May 2002.

Remarks. The four specimens were obtained from a native hunter on the market of Abomey who certified their origin as close to Didja. *C. senegalensis* – a species of the *C. dilepis* group without any traces of occipital flaps – was found on all markets in southern Benin and proved to be much more common than *C. gracilis*.

Eublepharidae

Hemitheconyx caudicinctus (Duméril, 1851)

Material examined. ZFMK 77066, near Didja, ZFMK 77067, Za-Kpota, both coll. by native collectors, 27 May and 18 June 2002, respectively.

Remarks. A West African species distributed from Senegal to Cameroon which has its southernmost localities in Benin. In Benin, it is termed "snake with two heads" by the locals and thought to be very dangerous.

Gekkonidae

Hemidactylus ansorgii Boulenger, 1901

Material examined. ZFMK 77073-075, Lama Forest (Noyeau Central), coll. by K. Ullenbruch, 18. (77073) and 28. April 2004.

Remarks. This slender, narrow-headed forest gecko with a long, cylindrical tail has only rarely been encountered and is known with certainty only from Liberia, Ivory Coast, Nigeria, and Cameroun (Henle & Böhme 2003). Bauer et al. (2006) expected *H. ansorgii* to occur in Benin, due to its wide West African distribution but stressed that there are no confirmed records from this country. Thus, our specimens represent the first record for Benin (Figure 9). The geckos were found in the late morning (11.30h–12.30h) on tree trunks in dense primary forest at about 1.7 m height.

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Fig. 9. *Hemidactylus ansorgei* from Lama Forest (Noyeau central), first country record. Photo: K. Ullenbruch

Fig. 10. *Hemidactylus angulatus* / *guineensis* complex: lectotype of *Hemidactylus guineensis* Peters, 1868. Photo: P. Wagner

Hemidactylus angulatus Hallowell, 1852

Material examined. ZFMK 42006-009, Godomey near Cotonou, coll. by W. Schröder, August/September 1984; ZFMK 77070, Bohicon, coll. by K. Ullenbruch, 17 April 2002; ZFMK 82813-814, Cotonou, coll. by Thibault Lachet, 22/23 April 2004.

Remarks. Thys van den Audenaerde (1967) distinguished between Hallowell's forest-dwelling species *Hemidactylus angulatus* and the savannah form *H. brookii guineensis* Peters, 1868. Since the African taxa of the former concept of an Afro-Indian species *H. brookii* Gray, 1845 are not at all close relatives of the true *H. brooki* from India (Carranza & Arnold 2006), it is still unclear whether the name *guineensis* should be treated as a synonym or a subspecies of *angulatus*, or possibly even a species. According to Bauer & Günther (1991), it is a synonym of *angulatus* (understood by these authors still as a subspecies of *H. brookii*).

Examination of the lectotype (Figure 10) of *H. guineensis* Peters, 1868 [described from "Ada Foah, Guinea" (= Adafoa, Ghana; **not** Adafer, Mauritania, as suggested by Loveridge 1947 and Wermuth 1965!) and compared by Peters (1868) only with *H. verruculatus* (= *H. turcicus*)] revealed that despite its provenance from coastal West Africa, it resembles the savannah form rather than the forest form which would strengthen a partial sympatry with the forest-dwelling *H. angulatus*. However, the distinguishing key character between both forms, i.e. the number of granules bordering the nostril above rostral and first supralabial (Thys van den Audenaerde 1967), has been disproved already by Böhme (1978), and other scalation differences also seem to be insufficient for a clear separation of both forms. Habitus differences could possibly be found in colour pattern, which often seems to consist of paired dorsal bars interrupted on the dorsal midline in the savannah populations, combined with more distinctly white-coloured single tubercles in the flank region. In the forest-dwelling populations, it consists of smaller, less symmetrically arranged darker elements, with less obvious white flank tubercles in the forest populations.

Steindachner (1870) described *H. affinis* from Gorée and Dagana, Senegal, and diagnosed it also only against *H. verruculatus* (= *H. turcicus*). He stressed the similarity of these two species, particularly concerning the size of their strongly keeled tubercles. The type series of *H. affinis* closely resembles the savannah-dwelling *H. guineensis*. In his description of *H. stellatus*, Boulenger (1885) compared it with *H. brookii* and *H. gleadovii* and stressed the presence of pure-white tubercles intermixed with a majority of dark brown ones which inspired him to the name *stellatus* (= starred). These white tubercles are indeed more obvious in the savannah-dwelling form (Figure 11) and

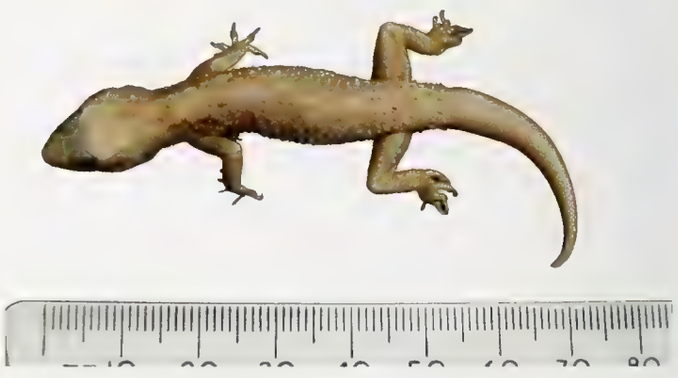

Fig. 11. *Hemidactylus angulatus* / *guineensis* complex: lectotype of *Hemidactylus stellatus* Boulenger, 1885. Photo: C. McCarthy

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Fig. 12. *Hemidactylus angulatus* (s.str.) from Godomey near Cotonou (left), *H. mabouia* from Cotonou (center) and *H.* aff. *mabouia,* also from Cotonou (right). Photo: P. Wagner

brought also Chabanaud (1917 a) to the conclusion that there are two different species in this group of geckos, viz. "*H. brookii*" (certainly meaning *angulatus*) and "*H. stellatus*" (= *H. guineensis*), at Agouagon, Benin, even in sympatry.

Preliminary genetic support for two species within a *H. angulatus/guineensis* complex may be deduced from the tree in Carranza & Arnold (2006) where a Kenyan Rift Valley sample is closer to dry savannah samples from Mauritania and Mali (*guineensis*) than to a forest sample from Bioko (*angulatus* s.str.). Moreover, as already pointed out by Thys van den Audenaerde (1967), the forest species *H. angulatus* does not occur in Central and East Africa.

Bauer et al. (2006) who provided locality data for many specimens of their *H. angulatus* (sensu lato) from all over Benin, did not distinguish between the two forms thus implying morphological uniformity, except their variable colour pattern. They stressed that the sympatric *H. mabouia* could be easily mixed up with *H. angulatus* what we also found to be true (but only for the forest form: *angulatus* s.str.) particularly when the diagnostic (see the key in Bauer et al. 2006) characters of tubercles on head and dorsum are concerned. Here, again the colour pattern of the dark phases of *H. angulatus* and *H. mabouia* may prove to be more reliable than the scalation (Figure 12). Concluding it becomes clear that *Hemidactylus angulatus* s.l. is in urgent need of a taxonomic revision throughout its range.

ZFMK 77070 was captured on a house wall on 19.30 h, i.e. 30 min. after sunset.

Hemidactylus fasciatus Gray, 1842

Material examined. ZFMK 82808, Forêt de Lama (Noyeau Central), coll. by Lamidi Konetche, April 2004.

Remarks. This species was first documented for Benin by Bauer et al. (2006) who recorded specimens from the vicinity of Kétou. Our record, the second for Benin, is from dense primary rain forest.

Hemidactylus mabouia Moreau de Jonnès, 1818

Material examined. ZFMK 77068-09, Cotonou, coll. by K. Ullenbruch, Datum; 82809-812, Cotonou (Maison des Stagnaires), coll. by Thibault Lachet, 22/23 April 2004.

Remarks. Not found by W. Schröder in 1984 and documented for the first time in Benin by Bauer et al. (2006). This species was considered to be rare in Nigeria and believed to be introduced in port cities by Dunger (1968). Also, Rödder & Böhme (2008) regarded it as endemic only in Central and East Africa, while it is an invasive species – next to South America, the Caribbean region and Florida – also in West Africa.

ZFMK 77068-09 differ from typical *H. mabouia* by lacking the very characteristic dark pattern of oblique curved cross stripes (Figure 12). Similar phenotypes have been found in western Guinea (Böhme et al., unpubl. data). As no scalation differences could be detected, we regard these specimens currently as a colour morph of *H. mabouia,* pending new material for genetic analyses.

The two specimens were collected by UK at noon time (12.00h) from house walls during a heavy thunderstorm rain. The geckos were observed to hunt for insects which were beaten to (or at least close to) the ground by the rainwater. The reduced daylight – a consequence of the dense clouds – might have helped the geckos to become active and to forage during midday. The masses of insects concentrating under these conditions within the lower two meters above the ground were also used and exploited by *Agama* aff. *agama* and *Mochlus guineensis*.

***Hemidactylus lamaensis* new species**

Holotype. ZFMK 77072, adult female, Forêt de Lama (teak plantation), coll. from a pitfall by Klaus Ullenbruch, 16 April 2002.

Diagnosis. A small *Hemidactylus* with a SVL of about 5.0 cm. Characteristic is the dorsal scalation which consists of numerous irregular rows of large, convex, keeled tubercles which are nearly juxtaposed on the dorsal hindpart and on the tail root, separated mostly by only one row of surrounding, rather coarse granular scales. Also the temple is covered by large, juxtaposed tubercles with only few or even without granules between them. Moreover, the subdigital lamellae of the first digit and toe are very low in number, the terminal unpaired lamella of digit I (manus) being the only adhesive element while digit I (toe) has two scansors: one divided proximal and one undivided terminal one.

Description of the holotype (Figure 13**)**. Habitus stout, head small with an elongated snout. Head & body length 47.7 mm, length of (regenerated) tail 34 mm. Snout elongate: distance from anterior margin of tympanum to hindmargin of eye 4 mm, from anterior margin of eye to tip of snout 5.5 mm; eye diameter 2.5 mm. Rostral broad, with a deep notch on its anterior midline which continues as a vertical suture but does not separate the rostral completely. Nostril bordered by rostral, a 1st labial, three postnasal scales, and a supranasal which is separated from its fellow by one single median scale. Scales on snout small but polygonal rather than granular, keeled, passing backwards into a tuberculate scalation of the frontal and parietal region which becomes intermixed with granules from the occipital region towards the neck and dorsum. Temple covered with conical tubercles with only few intermixed granules between them. Mouthline straight and not uplifted in its hindpart. Supralabials (left/right) 10/10, sublabials (left/right 8/8). Mental triangular, followed by two pairs of postmentals, the first of them broadly meeting at the midline behind mental. Gulars small, smooth, passing posteriorly gradually into the semicircle-shaped, subimbricate and likewise smooth chest and ventral scales. The conical and weakly keeled dorsal tubercles are arranged in 16–18 irregular longitudinal rows, circumdated by rather coarse granular scales which separate the tubercles by 1–3 rows, while on sacrum and tail root the tubercles are even nearly juxtaposed with only few scattered granules between them. Limbs covered above with coarse granular scales intermixed with conical, weakly keeled tubercles. Palmar scales smooth. All fingers and toes with distinct claws, and with divided adhesive lamellae (scansors) beneath, except the terminal one which is simple. Also the basal subdigital scales are undivided and are added to the number of subdigital lamellae when they are twice as large than the palmar scales. The values are: 1-5-6-7-6 (left manus), 1-5-6-7-5 (right manus), 2-6-7-8-7 (left pes), and 2-6-6-7-6 (right pes). The regenerated tail is dorsally covered with very regular subimbricate smooth scales which gradually pass into several longitudinal rows of obliquely enlarged, imbricate subcaudal plates.

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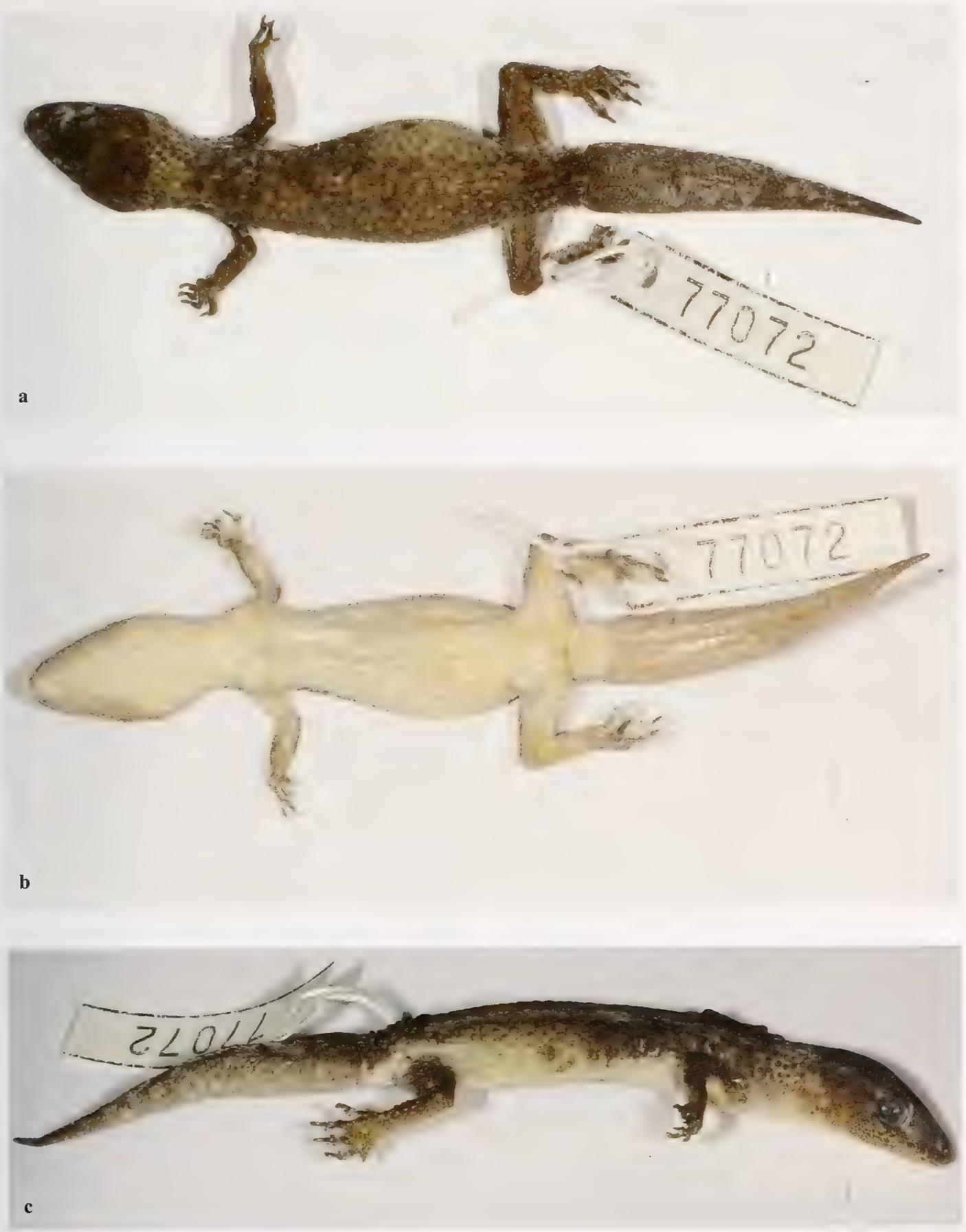

Fig. 13. *Hemidactylus lamaensis* n. sp., holotype from Lama Forest (Noyeau central) in dorsal (a), ventral (b) and lateral (c) view. Photo: P. Wagner

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Colour in preservative. Upper side rather uniformly light brownish, with a darker brown head, and one indistinct darker crossband on the neck and on the shoulder respectively. Underside uniform whitish-yellowish.

Etymology. The species name refers to Lama Forest, so far the only known locality of the new *Hemidactylus*. It is intended to stress the importance of this relict forest within the Dahomey gap also in conservational aspect as it may harbour still more unknown rain forest species.

Distribution and natural history. Only known from the type locality. The single female was taken from a pitfall on the forest floor in a young teak plantation bordering the primary forest of the Noyeau Central. This does not argue against an arboricolous lifestyle, because also tree-dwellers like *H. fasciatus* were observed to climb down from their shelter in big fig trees and to forage on the ground some hours after sunset (Böhme 1975).

Comparisons. This unique single specimen cannot be assigned to any West African species (see Bauer et al. 2006). Its snout is elongated but not to the extent observed in *H. ansorgei*. Its most obvious character is the possession of densely arranged, large, keeled tubercles which are less numerous as compared to those of the *H. angulatus/guineensis* complex. On the hindpart of the dorsum and the tail root, they are even nearly juxtaposed. Also in contrast to the situation found in the former complex is the dense coverage with tubercular scales of the temporal region. Moreover, it has the lowest number of subdigital lamellae of all Beninian and West African *Hemidactylus*.

Assuming that the original tail in this species has also series of tubercles (not present in the regenerated tail of the unique holotype), the key given by Bauer et al. (2006) for the geckos of Benin can be completed as follows:

13a. Dorsal tubercles prominent, keeled 14

13b. Dorsal tubercles not, or only weakly keeled, separated by one another by a distance greater than by tubercle width; dorsum of head atuberculate or with few small tubercles; color variable, the typical pattern of a series of dark curved crossbands distinct in the dark phase only ..... *Hemidactylus mabouia*

14a. Dorsal tubercles separated by one another by approximately the width of one tubercle; tubercles usually prominent on dorsum of head; temple granular .....*Hemidactylus angulatus/guineensis* complex

14b. Dorsal tubercles separated by one another by less than a tubercle width, on sacrum and tail root even abutting; temple covered with conical tubercles ..... *Hemidactylus lamaensis* **sp. nov.**

Scincidae

Panaspis togoensis (Werner, 1902)

Material examined. ZFMK 77079-080, Forêt de Lama, coll. by K. Ullenbruch, 24 and 28 April 2002.

Remarks. Both voucher specimens were collected in a transition zone of primary forest and a *Chromolaema* clearing, after heavy rainfalls around noon time. Considered to be ombrophilous by Perret (1973), activity after rains was also observed by Rödel et al. (1997). According to Fuhn (1972) and Schmitz et al. (2005), *Lygosoma (Riopa) dahomeyense* Chabanaud 1917 is a synonym of *P. togoensis*.

Mochlus guineensis (Peters, 1879)

Material examined. ZFMK 77076, Forêt de Lama; ZFMK 77077-078, Cotonou, all coll. by K. Ullenbruch, 16 and 13 April 2002 respectively.

Remarks. The specimen from Lama Forest was taken in a pitfall trap placed in an old teak plantation close to the primary forest. The two specimens from Cotonou were caught in the garden of a house during heavy rainfall when they were foraging for prey negatively influenced by the rains (see above, under *Hemidactylus mabouia*).

Remarkably, the specimen from Lama Forest differs in some characters from the two Cotonou specimens. It is more delicately built, having thinner limbs and a longer and slimmer tail. Moreover, the eyes seem to be smaller, the overall colouration is distinctly darker, and the subcaudal scales are spotted with black, while the Cotonou specimens have the underside of their tails purely white. More material is necessary to evaluate these differences (Figure 14).

Trachylepis affinis (Gray, 1838)

Material examined. ZFMK 42004-005, Godomey near Cotonou, coll. by W. Schröder, August/September 1984; ZFMK 77081-090, Forêt de Lama, coll. by K. Ullenbruch, 16 April to 1 May 2002.

Remarks. The two specimens from Godomey come from a farmland/garden environment, the Lama Forest individuals, however, were all collected within dense primary forest (Noyeau Central), on clearings grown with *Chromolaema*, and in the neighbouring teak plantations. The lizards were found either in leaf litter and on the grassy floor, or on tree trunks. When disturbed they tried almost

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Fig. 14. *Mochlus guineensis*, from Cotonou (above) and Lama Forest (Noyeau central) (below). Photo: P. Wagner

invariably to escape upwards. They were mainly active between 11.00h and 15.00h, at air temperatures of 31–32°C.

Half of the Lama Forest sample has a distinctly striped colour pattern with a conspicuous, white sublabial stripe running along the lower flank towards the tail, while the other half lacks this stripe.

Trachylepis perroteti (Duméril & Bibron, 1839)

Material examined. ZFMK 41998-999 (2 males), Godomey near Cotonou, coll. by W. Schröder, August/Septeber 1984.

Remarks. According to Mausfeld-Lafdhyia et al. (2004) and Chirio & LeBreton (2007), *T. perroteti* consists of at least two distinct species which require further study (see also Stoll 2008). But because the true *T. perroteti* (s.str.) is the more southernly distributed from of the two cryptic siblings in Cameroon, the two males from near Cotonou are most likely belonging to this latter species. Whether this is also true for the North Beninian populations (see the country checklist below) remains to be studied.

Lacertidae

Holaspis guentheri Gray, 1863

Material examined. ZFMK 77071, Forêt de Lama (teak plantation), coll. by K. Ullenbruch, 26 June 2002.

Remarks. The only voucher specimen was obtained from an arthropod trap (trunk eclector) fixed on a dead teak tree (*Tectona grandis*) within an old teak plantation bordering the primary forest of Forêt de Lama. This little lacertid with the ability of gliding flight has not been recorded so far from Benin, thus representing the first country record.

Varanidae

Varanus exanthematicus (Bosc, 1792)

Material examined. ZFMK 77004-005, near Didja, coll. by local hunter, 1 May 2002.

Remarks. Both specimens were obtained from a local hunter at Abomey who certified their origin as being close to Didja.

Varanus niloticus (Linnaeus, 1766)

Material examined. ZFMK 42200, Godomey near Cotonou, coll. by W. Schröder, August/September 1984; ZFMK 77001, juv., Ouémé River near Togbota, coll. by local hunter, 15 April 2002.

Remarks. ZFMK 77001 was found under a heap of dry wood on the bank of a small tributary of the Ouémé River, close to the settlement of Togbota.

Varanus ornatus (Daudin, 1803)

Material examined. ZFMK 77002-003, near Didja, coll. by native hunter, 10 and 30 May 2002 respectively.

Remarks. Both specimens were obtained from local hunters at Abomey who had collected them in the vicinity of Didja. One of them originated from Lakpo, 8 km NE of Didja, which is in immediate vicinity of a further relict forest patch, viz. Forèt de Dan. A big, adult specimen was seen in hectic flight in Lama Forest and could not be caught.

On markets, *V. ornatus* was much less commonly seen than *V. niloticus* which reflects also the scarcity of relict forest patches in the Dahomey gap which serve as refugia for this forest species. For Benin, our specimens represent the first country record (Böhme & Ziegler 1997).

Pythonidae

Python regius (Shaw, 1802)

Material examined. ZFMK 41993-995, Godomey near Cotonou, coll. by W. Schröder, August/September 1984; Photographs from Za-Kpota and Forêt de Lama.

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Remarks. Of ZFMK 41995, only head and neck are preserved. This species was seen in great numbers on all markets visited. These great numbers certainly pose a serious conservation problem which could be buffered by farming royal pythons for the international pet trade. However, such farms will be very difficult to be controlled as far as wild-caught specimens are concerned.

Python sebae (Gmelin, 1788)

Material examined. None.

Remarks. Rock pythons could be seen only twice on markets by UK during his survey. He was told by the people that they fear the large snakes and normally kill them whenever possible. This species is subject to superstitious beliefs by the local people. For instance, a scientific assistant of the BIOLAMA project even told that rock pythons are capable to cast out a net out of their mouth to catch humans and to eat them subsequently.

Colubridae (sensu lato)

Afronatrix anoscopus (Cope, 1861)

Material examined. ZFMK 77006 (juvenile), Forèt de Lokoli, coll. by K. Ullemnbruch, 5 May 2002.

Remarks. The existence of this aquatic species in Benin was considered as likely by Chippaux (2001). Our specimen (Figure 15) was the first documented record from Benin until very recently Chirio & Ineich (2009) published a find from Atakora Province which makes our specimen the 2nd published record. It is, however, still interesting to note that both new records of this species are very distant from each other, ranging from a relict, swampy rain forest to dry Sudan savannah.

Crotaphopeltis hotamboeia (Laurenti, 1768)

Material examined. ZFMK 42001-002 (juveniles), Godomey near Cotonou, coll. by W. Schröder, August/September 1984.

Remarks. None.

Dasypeltis gansi Trape & Mané, 2006

Material examined. ZFMK 77014, Za-Kpota, coll. by native hunter, may 2002.

Fig. 15. *Afronatrix anoscopus,* juvenile, from Lokoli Forest, first country record. Photo: K. Ullenbruch

Remarks. Trape & Mané (2006 a) partitioned the West African egg-eater snakes formerly referred to as *D. scabra* into 3 different species, one of them with a likewise new subspecies: *D. confusa, D. gansi* (with *D. g. gansi* and *D. g. latericia*), and *D. sahelensis*. According to the original description and to the key and colour plates of Trape & Mané (2006 b) the specimen from Za-Kpota clearly represents the nominotypic subspecies of *D. gansi*. It is the second voucher from Benin, the first (Trape & Mané 2006 a) Benin record being from Lanta (where it is, according to the same authors, sympatric with *D. confusa*). The record of Chabanaud (1916) of "*D. scabra palmarum*" refers very likely also to *D. g. gansi* which is the only of the newly described taxa which tends to be patternless.

Dispholidus typus (Smith, 1829)

Material examined. ZFMK 77029, between Bohicon and Didja, coll. by K. Ullenbruch, May 2002.

Remarks. Found dead on the road between the two abovementioned places.

Lamprophis fuliginosus (Boie, 1827)

Material examined. ZFMK 77011, Didja; 77015-017, Za-Kpota; 77041, Forêt de Lama; 77051, Forêt de Dan, all coll. by K. Ullenbruch, 14–18 June 2002.

Remarks. ZFMK 77041 was found dead on a path within Lama Forest, just between primary forest and the neighbouring teak plantation. Although still rather fresh, its head was already badly damaged by ants.

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Lycophidion semicinctum Duméril, Bibron & Duméril, 1854

Material examined. 77007, near Didja, coll. by native hunter, May 2002; ZFMK 77050, near Bohicon, coll. by K. Ullenbruch, May 2002.

Remarks. The Bohicon specimen was found dead on a road.

Meizodon regularis Fischer, 1856

Material examined. ZFMK 42003, Godomey near Cotonou, coll. By W. Schröder, August/September 1984.

Remarks. Known from, among else, Ghana (where the type locality is situated), and Togo west of Benin, as well as from Cameroon further east (Roux Estève 1969), this species was to be expected in Benin but was obviously only indicated for Benin by Chippaux (2001). ZFMK 42003 represents the second country record and first published voucher specimen for Benin.

Natriciteres olivacea (Peters, 1854)

Material examined. ZFMK 77039, Forêt de Lama, coll. by K. Ullenbruch, May 2002.

Remarks. Found on a cloudy day at 11.20h on the forest floor. This underlines that this species is not confined to savannah habitats as claimed by Broadley (1983) but that at least in West Africa also forests are inhabited (see Villiers 1975, Chippaux 2001: distribution map).

Natriciteres variegata (Peters, 1861)

Material examined. ZFMK 77042-046, Forèt de Lama, coll. by K. Ullenbruch, May 2002.

Remarks. All five individuals were found on the forest floor. The species proved to be rather common but was never seen outside the forest. Also Dunger (1972a), Broadley (1983) and Chippaux (2001) regard *N. variegata* as a forest species. The only earlier record of it was Chabanaud's report from "Dahomey", thus our small series represents the first documented locality record for Benin.

Philothamnus irregularis (Leach, 1819)

Material examined. ZFMK 77025-026, Za-Kpota, coll. by native snake hunter, May 2002; ZFMK 77040, Forét de Lama: Koto village, coll. K. Ullenbruch, May 2002.

Remarks. The last mentioned specimen was killed by a local farmer in the presence of KU on a sun-exposed grassy area.

Philothamnus semivariegatus (Smith, 1847)

Material examined. ZFMK 77034-035, Bohicon, coll. by K. Ullenbruch, May 2002.

Remarks. Both snakes were encountered on the compound of a mill. One of them was found on the floor of a house belonging to that compound. Encounters in human habitations and even within buildings were also reported from Nigeria by Dunger (1973a).

Psammophis elegans (Shaw, 1802)

Material examined. One specimen, uncatalogued, Cotonou (stored in the private collection of M. Serge Attignon, Cotonou), coll. by a S. Attignon, 11 May 2002.

Remarks. The only available specimen of this snake was found in front of a house in the outskirts of Cotonou.

Psammophis phillipsi (Hallowell, 1844)

Material examined. ZFMK 41996, Godomey near Cotonou, coll. by W. Schröder, August/September 1984.

Remarks. The large adult, dark-brown unicoloured female is allocated to Hallowell's species because the mid-region of its ventral plates has a broad median zone shaded with bluish-grey colour. We think that this is a species of forested and moist savannahs which is unicoloured above already as a juvenile has and lacks the typical striped juvenile dress of the following form (Böhme et al. 1996).

Psammophis cf. *phillipsi* (Hallowell, 1844)

Matèrial examined. ZFMK 77024 & 77028, Za-Kpota, coll. by a native snake hunter, May 2002; ZFMK 77047, Abomey, coll. by K. Ullenbruch, May 2002.

Remarks. The three specimens belong to the big-growing form of the *Psammophis sibilans* species complex which is dorsally striped as a juvenile and unicoloured above and below as a large, old adult. It inhabits the dry Sudanian and Sahelian savannahs and is mostly referred to as *P.* cf. *phillipsi* (e.g. Böhme 1978, Böhme et al. 1996) or, recently, again as true *P. sibilans* (Trape & Mané 2006 b). Al-

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Fig. 16. *Psammophis sudanensis* from Bohicon, southern Benin. Photo: K. Ullenbruch

Fig. 17. The same specimen from below. Photo: K. Ullenbruch

so earlier records of *P. sibilans* from West Africa (e.g. Chabanaud 1916) refer to this form which, in our opinion, is not conspecific with the true *P. sibilans* from Egypt. Many not yet fully grown but nonetheless adult (mature) specimens may retain more or less distinct reddish dorsolateral stripes along the body. The belly is light whitish to yellowish and patternless (no dark hairlines along the ventral plates), but supralabials, sublabials and gulars show some dark pigmented spots (see Böhme et al. 1996). The anal shield is entire. Its taxonomic status and nomenclatural status needs still to be assessed.

Psammophis sudanensis Werner, 1919

Material examined. ZFMK 77012, Didja, coll. native hunter; ZFMK 77018-019; ZFMK 77036-038, Bohicon, and ZFMK 77047, Abomey, all coll. by K. Ullenbruch, May 2002.

Remarks. The specimens represent various age classes. All have distinct hairlines along the outer parts of the ventral shields, however, these hairlines are brownish in younger and darker in the older individuals. The zone between these hairlines is differently coloured than the two outer, ventrilateral zones, the latter being white while the inner is yellowish-whitish. This ventral pattern is therefore of the "*subtaeniatus* type" and agrees with the type specimen of *sudanensis* Werner, 1919 (NMW 1986 from Kadugli, Kordofan) which actually was described as *P. **subtaeniatus** sudanensis* (Werner 1919, Böhme 1987). In all specimens, the anal shield is divided.

ZFMK voucher specimens from e.g. northern Senegal (Dakar, Fété Olé), Algeria (Tamanrasset), North Cameroon (Mokolo) (see Böhme 1986) and Chad (ZFMK 74520) are very close to typical *P. sudanensis* but differ in having either faint, light brown hairlines (instead of blackish ones) or no hairlines at all; their undersides are in both cases of a uniform, bright porcellanic white. They correspond to the type specimen of *P. leucogaster* Spawls, 1983 (BMNH 1980: 261, from Wa, northern Ghana, see Spawls 1983), and further sampling must show whether both forms have zones of intergradation. It seems that if there is a distinction between typical *sudanensis* and *leucogaster* in West Africa, this is a question of a north-south rather than a west-east disjunction.

ZFMK 77036-038 were found on the compound of a mill at Bohicon. One of them was lying in the afternoon on the terrace of a house, the other two were killed during grass mowing (Figs 16 and 17).

Rhamphiophis oxyrhynchus (Reinhardt, 1843)

Material examined. ZFMK 41997, Godomey near Cotonou, coll. by W. Schröder, August/September 1984; ZFMK 77020-023, Za-Kpota, coll. by a native hunter, May 2002.

Remarks. None.

Scaphiophis albopunctatus Peters, 1870

Material examined. ZFMK 77009-010 (juvenile and adult), Didja, collected by a local snake hunter, May 2002.

Remarks. The juvenile specimen contained 3 newborn mice which could not be identified to the familial or generic level.

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Atractaspididae

Amblyodipsas unicolor (Reinhardt, 1843)

Material examined. ZFMK 77027, Za-Kpota, coll. by native hunter, May 2002.

Remarks. When fixing this snake, some white nematodes appeared between the scales and tried to leave the specimen. This was not observed in any other snake during preparation.

Elapidae

Dendroaspis viridis (Hallowell, 1844)

Material examined. ZFMK 77049, Bohicon (market), coll. by K. Ullenbruch, May 2002.

Remarks. Since this snake was found on a market, no further information on its precise provenance is available.

Elapsoidea semiannulata Bocage, 1882

ZFMK 77013, near Didja, coll. by a native snake hunter, May 2002.

Remarks. Represents the West African subspecies *E. s. moebiusi* Werner,1897 (Trape & Mané 2006).

Naja nigricollis Reinhardt, 1843

Material examined. ZFMK 77032, Forèt de Lama; ZFMK 77033, Bohicon, both coll. by K. Ullenbruch, May 2002.

Remarks. One of the two juvenile specimens was found dead on a road at the margin of Lama Forest, the other was killed during grass mowing in the mill compound of Bohicon.

Viperidae

Bitis arietans (Merrem, 1820)

Material examined. ZFMK 77048, environs of Abomey, coll. by native hunter, May 2002.

Remarks. *B. arietans* is very commonly offered on markets. Usually, the head is cut off, dried and used for Voodoo ceremonies while the rest of the animal is used as food.

Causus maculatus (Hallowell, 1842)

Material examined. ZFMK 77030, between Bohicon and Didja, ZFMK 77031, 9 km east of Abomey, both coll. by K. Ullenbruch, May 2002.

Remarks. The first specimen of this ubiquitous species was found dead on the asphalt road between Bohicon and Didja, the second one was killed by locals next to the street to Abomey in a crop field.

Echis ocellatus Stemmler, 1970

Material examined. ZFMK 77008, near Didja, coll. by local snake hunter, May 2002.

Remarks. None.

CONCLUSIONS

Of the 48 species recorded above from several localities in southern Benin, including the relict rain forests Forêt de Lama and Forêt de Lokoli, only eight can be regarded as true forest species. These are: *Agama sylvanus*, *Hemidactylus ansorgei*, *H. fasciatus*, *H. mabouia*, *H. lamaensis* sp. n., *Holaspis guentheri*, *Varanus ornatus*, and – as the only snake – *Psammophis phillipsi*. Two of them, *Hemidactylus fasciatus* and *H. mabouia*, are recorded from Benin for the second time, *H. mabouia*, however, being a recent invasive colonizer. The remaining five lizard species, all from Lama Forest, are first country records for Benin, one of them, *H. lamaensis* sp. n., being new to science.

Three snake species, viz. *Afronatrix anoscopus*, *Amblyodipsas unicolor*, and *Natriciteres variegata*, are found in both forest and savannah habitats. Of these, *Afronatrix anoscopus* is recorded here for the second time from Benin, but for the first time from southern Benin (the very recent first record being from the Atakora chain in the northwestern part of the country). *Amblyodipsas unicolor* and *Natriciteres variegata* are both representing the respective first country records documented by voucher specimens.

The remaining 40 species are widely distributed in the West African savannas and have in most cases been recorded from Benin before. Nonetheless, particularly some snakes have been listed and/or plotted in maps of review papers and books by e.g. David & Ineich (1999), Chippaux (1999, 2001, 2006), or Trape & Mané (2006 b) without locality and voucher documentation of the respective country records, so that our specimens are in some

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cases nonetheless the first documented records, despite earlier citations of the respective species from Benin.

In the following country-wide checklist, we included also some new data derived from the mission to Pendjari National Park by one of authors (OG). Among these, the by far most remarkable find is the rediscovery of *Agama gracilimembris* in Benin, from where it was first described about ninety years ago.

COUNTRY-WIDE CHECKLIST OF THE REPTILES OF BENIN

The following list contains several records of species collected by the Lama Forest survey of the senior author which have not been documented before from the territory of Benin. However, as nearly all these species were already known from the neighbouring countries in the west (Togo) and in the east (Nigeria), their presence in Benin is not surprising and was already regarded as probable in several cases by Villiers (1951), Chippaux (2001) or Bauer et al. (2006). More general books on West Africa or even Africa as a whole (e.g. Villiers 1976, Welch 1982, Chippaux 1999, 2001, 2006, Trape & Mané 2006 b) often pose the problem that a species is assumed to occur in a specific country (e.g. formulations as "from Senegal to Uganda") rather than being documented from a specific locality within the respective country; or that it is plotted on a map without documentation of the origin of the respective data.

For completeness' sake, we included in this list some species recorded by Chabanaud (1916) which are definitely lacking in West Africa and thus are probably due to misidentifications. They are marked with an asterisk (*). A re-examination of the respective voucher material as far as still extant was, however, beyond the scope of this paper. It is also noted here that the most important place of origin of Chabanaud's material collected by Dr. Bouet is constantly spelled Agoua**gon** in his papers, as it is also by Villiers (1951). However, more recent authors (e.g. Hoogmoed 1974, Salvador 1982) spell it "Agoua**gou**" under which name it is also found on modern road maps. Here, we follow the original spelling.

It was reflecting the still poor state of knowledge of the reptilian fauna of Benin when Loveridge (1952) stated that among the turtles and lizards from the A. Villiers mission (1950) no less than 8 species were new for the country, among them even *Agama agama*! More than five decades later Bauer et al. (2006) recorded – next to more first records of geckos and a new species of *Hemidactylus* – also the common *H. mabouia* as new for the country, and in this paper, we can list – again next to another new *Hemidactylus* – further 8 species as new for Benin's reptile fauna. Our reference to Pendjari NP and to Bemberéké are based on data and photographic documentations collected by one of us (OG) and of a small donation of snakes to ZFMK by T. & M. Imthurn (2000). For the latter, the ZFMK catalogue numbers are given.

Geoemydidae

**Mauremys leprosa* – Chabanaud (1917): Porto Novo (as *Clemmys leprosa*). Not in Fritz & Havas (2007). According to Fritz (pers. comm.) this record is certainly due to an error and should be deleted from the country's species list.

Testudinidae

Kinixys belliana nogueyi – Loveridge (1951): Bassila; this paper: Bohicon-Abomey area; Pendjari NP.

Pelomedusidae

Pelomedusa subrufa – Loveridge (1951): Bassila; Zagnanado; this paper: Lama Forest surroundings; Pendjari NP.

Pelusios castaneus – Sinsin et al. (1999): Benin, unspecified (as *P. subniger*); Branch (2008): on map, but without locality data; this paper: Lama Forest surroundings; Pendjari NP (ZFMK 83613).

Trionychidae

Cyclanorbis elegans – Gramentz (2008): "Benin", without specific locality.

Cyclanorbis senegalensis – Gramentz (2008): Pendjari NP (based on Grell 2003); this paper: Pendjari NP (Figure 18).

Crocodylidae

Crocodylus suchus – This paper: Pendjari NP (Figure 19).

Osteolaemus tetraspis – Sinsin et al. (1999): "Sud-Bénin" including the Departments of Zou, Mono, Ouémé, and Atlantique.

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Fig. 18. Cyclanorbis senegalensis, juvenile from Pendjari NP, northern Benin. Photo: O. Grell

Eublepharidae

Hemitheconyx caudicinctus – Chabanaud (1917 a): "Haute Dahomey"; Agouagon (as *Psilodactylus caudicinctus*); Bauer et al. (2006): Kétou; Diho (=Idiho); this paper: Didja; Za-Kpota.

Gekkonidae

Hemidactylus ansorgei – This paper: Lama Forest (1st country record).

Hemidactylus angulatus/guineensis complex – Chabanaud (1917 a): Agouagon (as *H. brookii* and *H. stellatus*); Grandison (1956, in part): "Dahomey"; Loveridge (1947): Ajuda; Godomey; Grand Popo; Porto Novo; Zomai; Loveridge (1952): Abomey; Bassila; Koussoukoingou; Bauer et al. (2006): Attogon; Niaouli; Abomey; Collines du Dassa-Zoumè; Manigri; Pendjari NP; this paper: Godomey; Bohicon.

Hemidactylus beninensis – Bauer et al. (2006): Collines du Dassa-Zoumè (new species description).

Hemidactylus fasciatus – Bauer et al. (2006): near Kétou; this paper: Lama Forest (2nd country record).

Hemidactylus mabouia – Bauer et al. (2006): Godomey, Abomay, Niaouli; this paper: Cotonou (2nd country record).

Hemidactylus muriceus – Bauer et al. (2006): near Kétou.

Hemidactylus lamaensis – This paper: Lama Forest (new species description).

Lygodactylus conraui – Bauer et al. (2006): Lokoli Forest.

Phyllodactylidae

Ptyodactylus ragazzii – Bauer et al. (2006): Chutes de Koudou, PN du W.

Tarentola ephippiata – Bauer et al. (2006): Pendjari NP.

Fig. 19. *Crocodylus suchus*, Pendjari NP. Photo: O. Grell

Fig. 20. *Agama gracilimembris*, Pendjari NP, first rediscovery in Benin after its first description from this country nine decades ago. Photo: O. Grell

Agamidae

Agama agama complex – Loveridge (1952): Bassila; Koutiacou; Zagnanado; this paper: Godomey nr. Cotonou; Cotonou; Bohicon; Pendjari NP.

Agama sylvanus – This paper: Lama Forest (1st country record).

Agama gracilimembris – Chabanaud (1918): "Dahomey" (original description); this paper: Pendjari NP.

Note: This little agama with unresolved intrageneric relationships was subsequently found in Nigeria and in the Central African Republik (Grandison 1968, 1969, Joger 1990), the gap between these two records being bridged by a find in northern Cameroon (Böhme 1975). The photographic record from Pendjari NP (Figure 20) is the first find of this rare agama in Benin since its original description in 1918, a rediscovery after 9 decades!

Chamaeleonidae

Chamaeleo africanus – This paper: Atakora chain (1st country record, based on photograph).

Note. A photograph of a "chameleon" published in a popular book on Benin by Englebert (1973, cited after Conrad 1999) without identifying the species shows clearly a specimen of *C. africanus*. Its inclusion by Conrad (1999) into her unpublished thesis means that it is still the first published country record for Benin.

Chamaeleo gracilis – This paper: Abomey-Didja; Pendjari NP.

Chamaeleo necasi – Ullenbruch et al. (2007), this paper: Bohicon-Za-Kpota, Houegbo.

Chamaeleo senegalensis – Loveridge (1952): Zagnanado; this paper: Bohicon; Abomey-Didja; Pendjari NP.

Scincidae

Chalcides thierryi – Loveridge (1952): Koussokoingou (as *Chalcides ocellatus thierryi*).

Mochlus guineensis – Chabanaud (1917): Agouagon; this paper: Lama Forest; Cotonou.

Panaspis togoensis – Chabanaud (1917): Agouagon (as *Lygosoma (Riopa) dahomeyense*, syn. fide Schmitz et al. 2005); Loveridge (1952): Bassila (as *Lygosoma (Panaspis) breviceps togoense*) Grandison (1956): "Dahomey" (as *P. breviceps togoense*); Fuhn (1972): "Dahomey: Agouagou" (as *Panaspis kitsoni*); this paper: Lama Forest; Pendjari NP.

Trachylepis affinis – Chabanaud (1917): Satadougou (as *Mabuia raddonii*); Loveridge (1952): Abomey; Bassila; Koussokoingou; Tanogou (as *Mabuya blandingii*); this paper: Godomey nr. Cotonou; Lama Forest; Pendjari NP.

Trachylepis perrotetii – Chabanaud (1917): Agouagon (in part as *Mabuia albilabris,* fide Hoogmoed 1974); Loveridge (1952): Abomey; Bassila; Koussokoingou (as *Mabuya perroteti*); this paper: Godomey nr. Cotonou; Pendjari NP.

Trachylepis maculilabris – Chabanaud (1917): Agouagon; Loverdige (1952): Bassila.

Trachylepis quinquetaeniata sharica Sternfeld, 1917 – Chabanaud (1917): Agouagon (in part as *Mabuia albilabris*, fide Hoogmoed 1974); Loveridge (1952): Bassila (as *Mabuya quinquetaeniata sharica*); this paper: Pendjari NP.

Gerrhosauridae

Gerrhosaurus major zechi – Loveridge (1952): Koussokoingou.

Lacertidae

Acanthodactylus boueti – Chabanaud (1917): Agouagon (as *A. (Latastia) boueti*); Loveridge (1952), Salvador (1982): Bassila.

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Heliobolus nitidus – Loveridge (1952): Bassila (as *Eremias n. nitida*); this paper: Pendjari NP.

Holaspis guentheri – This paper: Lama Forest (1st country record).

Amphisbaenidae

Cynisca leucura – Chabanaud (1917a): Agouagon; "Dahomey" (as *Amphisbaena leucura*); Loveridge (1952): Natitingou.

Varanidae

Varanus exanthematicus – This paper: Abomey-Didja.

Varanus niloticus – Chabanaud (1917a): Agouagon; "Haut Dahomey"; this paper: Godomey nr. Cotonou; Ouémé River near Togbota; Pendjari NP (photographic voucher of an unusually pale olive-coloured juvenile, Figure 21).

Varanus ornatus – This paper: Abomey-Didja; Lama Forest (1st country record).

Leptotyphlopidae

Leptotyphlops bicolor – Chabanaud (1916): Porto Novo (as *Glauconia. b. gruveli*).

Leptotyphlops brevicauda – Bocage (1887): "Dahomey" (as *Stenostoma brevicauda*); Hahn (1980): "Dahomey" (as *Leptotyphlops brevicaudus*).

**Leptotyphlops nigricans* – Chabanaud (1916): "Dahomey" (Identification probably erroneus, taxon not in west Afria).

Typhlopidae

Ramphotyphlops braminus – Trape & Mané (2006 b): Cotonou.

Typhlops punctatus – Chabanaud (1916): "Dahomey"; Chabanaud (1917a,b): Ouidah, Agouagon.

Boidae

Gongylophis muelleri – Trape & Mané (2006 b): on grid map but without specific locality.

Fig. 21. *Varanus niloticus*, subadult, unusally light-coloured specimen from Pendjari NP. Photo: O. Grell

Python regius – Villiers (1951): "très commun", voucher specimen from Abomey; this paper: Godomey nr. Cotonou; Za-Kpota; Lama Forest.

Python sebae – Villiers (1951): "Très commun partout", specimens from Abomey; this paper: South Benin.

Colubridae

Afronatrix anoscopus – Chirio & Ineich (2009): Niangou NE of Tanguieta; Atakora Prov.; this paper: Lokoli Forest (2nd published country record, regarded already as probably present by Villiers 1951 and Chippaux 2001).

Bamanophis dorri – Chippaux 1999, 2006; N Benin: unspecified (as *Coluber dorri*); Trape & Mané (2007): on grid map but without specific locality (as *Hemorhhois dorri*; Schätti & Trape (2008): unspecified.

Crotaphopeltis hippocrepis – Rasmussen (2000): Soubroukou.

Crotaphopeltis hotamboeia – Chabanaud (1916): "Dahomey" (as *Leptodira hotamboeia*); Chabanaud (1917 b): Agouagon (as *Leptodira hotamboeia*); this paper: Godomey nr. Cotonou.

Dasypeltis gansi – Chabanaud (1916): "Dahomey" (as *D. scabra palmarum*); Trape & Mané (2006 a): Lanta; this paper: Za-Kpota.

Dispholidus typus – This paper: Bohicon-Didja (1st country record; regarded as probably present by Villiers 1950).

Grayia smythii – Chabanaud (1916): near Sakété, Porto-Novo.

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Hormonotus modestus – Chabanaud (1916): "Dahomey"; Chabanaud (1917 b): near Lac Azzi.

Lamprophis fuliginosus – Chabanaud (1916): "Dahomey" (as *Boaodon fuliginosus*); Chabanaud (1917b): Agouagon (as *Boodon fuliginosus*); Villiers (1951): Koussokoingou/Atakora (as *Boaedon fuliginosus*); this paper: Dan Forest; Lama Forest; Didja, Za-Kpota.

Lamprophis lineatus – Chabanaud (1916): "Dahomey" (as *Boaodon linatus*); Chabanaud (1917b): Agouagon (as *Boodon lineatus*); Villiers (1951): Abomey (as *Boaedon lineatus*).

**Lycophidion capense* – Chabanaud (1916): "Dahomey" (listing of *capense* and *capense multimaculatum* probably due to identification error: both taxa not in West Africa).

Lycophidion semicinctum – Villiers (1951): Abomey; this paper: Bohicon; Didja.

Mehelya crossi – Chabanaud (1916): "Haut-Dahomey" (as *Simocephalus capensis*); Loveridge (1940): Bassila; Villiers (1951): Abomey.

Meizodon coronatus – Trape & Mané (2006 b): on grid map but without specific locality.

Fig. 22. *Psammophis elegans* from Pendjari NP, dorsal pattern. Photo: O. Grell

Meizodon regularis – Chippaux (2001): Benin (on map, without documented locality); this paper: Godomey nr. Cotonou (2nd country record).

Natriciteres olivacea – Chabanaud (1916): "Dahomey" (as *Tropidonotus olivaceus*); this paper: Lama Forest (1st documented locality record for Benin).

Natriciteres variegata – This paper: Lama Forest (1st country record).

Philothamnus irregularis – Trape & Mané: on grid map but without specific locality; this paper: Lama Forest.

Philothamnus semivariegatus – Chabanaud (1916): "Dahomey"; Chabanaud (1917a): Cotonou, Agouagon; Villiers (1951): Abomey; this paper: Lama Forest.

Polemon neuwiedii – Chabanaud (1916): "Dahomey" (as *Miodon neuwiedi*); Agouagon (as *Miodon neuwiedi*).

Prosymna meleagris – Chabanaud (1916): "Dahomey"; Chabanaud (1917a): Agouagon.

Psammophis elegans – Loveridge (1941): Ouidah; this paper: Cotonou; Bembéréké ZFMK 72885); Pendjari NP (Figure 22).

Psammophis lineatus – Chabanaud (1916): "Dahomey"; Chabanaud (1917 b): Agouagon.

Psammophis cf. *phillipsi* – Chabanaud (1916) "Dahomey" (as *P. sibilans*); this paper: Abomey; Za-Kpota; Pendjari NP (Figure 23).

Psammophis phillipsi (s.str.) – Chabanaud (1916): "Dahomey" (as *P. regularis*); this paper: Godomey near Cotonou.

Psammophis praeornatus – Chabanaud (1916): "Dahomey" (according to Villiers 1951 not documented).

Psammophis schokari – Chabanaud (1916): "Dahomey" (as *P. shokari*: considered to be of doubtful provenance by this author).

Psammophis sudanensis – This paper: Didja; Za-Kpota, Abomey, Bohicon (1st country record).

Rhamphiophis oxyrhynchus – Chirio & Ineich (1991): Benin, unspecified; Trape & Mané (2006): on grid map, but without specific locality; this paper: Godomey nr. Cotonou; Za-Kpota.

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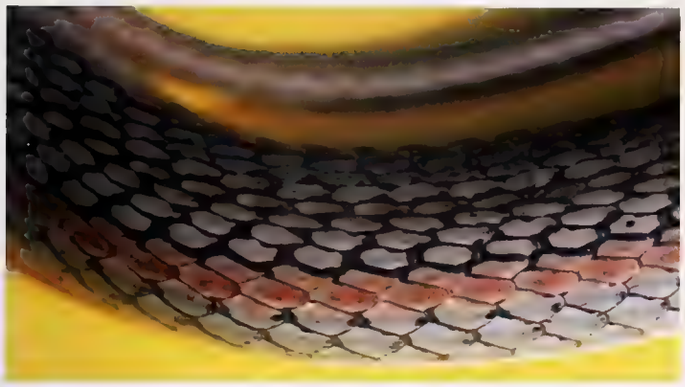

Fig. 23. *Psammophis* cf. *phillipsi* from Pendjari NP, showing the characteristic reddish dorsilateral stripes. Photo: O. Grell

Scaphiophis albopunctatus – Bocage (1895, 1896): Ajuda; Chabanaud (1916): "Dahomey"; Chabanaud (1917a): Agouagon; Broadley (1994): Parakou, and Segbana; this paper: Lama Forest (Didja).

Telescopus variegatus – Chabanaud (1916): "Dahomey" (as *Tarbophis variegatus*); Chabanaud (1917a): Agouagon (as *Tarbophis variegatus*); Villiers (1951): Abomey (as *Tarbophis variegatus*).

**T. semiannulatus* – Chabanaud (1916): "Dahomey" (as *Tarbophis semiannulatus*. Repeated by Villiers (1951), but probably due to misidentification, as taxon not in present in West Africa).

Thelotornis kirtlandii – Villiers (1951): Bassila.

Toxicodryas blandingii – Chabanaud (1916): "Dahomey" (as *Dipsadomorphus blandingii*); Villiers (1951): Zagnanado, Abomey (as *Boiga blandingii*).

Toxicodryas pulverulentus – Chabanaud (1917b): Porto Novo (as *Dipsadomorphus boueti*, syn. fide Villiers 1951).

Atractaspididae

Amblyodipsas unicolor – Considered to be probably in Benin by Villiers (1950) and Meirte (1999); Chippaux (2001): On map, but without documented locality; this paper: Za-Kpota (first documented country record).

Aparallactus modestus – Boettger (1898): Grand Popo; Witte & Laurent (1947): "Gross Popo".

Atractaspis aterrima – Villiers (1951): Abomey; Rasmussen (2005): "Benin, without locality".

Atractaspis dahomeyensis – Barboza du Bocage (1887): Zomai; Villiers (1951): Abomey; Trape & Mané (2006b): Parakou.

Atractaspis watsoni – Trape & Mané (2006 b): on grid map but without specific locality.

Elapidae

Dendroaspis viridis – Chabanaud (1916): "Dahomey" (as *Dendraspis viridis*); this paper: Bohicon.

Elapsoidea semiannulata moebiusi – Chabanaud (1916): "Dahomey" (as *Elapechis guentheri*); Chabanaud (1917 b): Agouagon (as *Elapechis guentheri*); this paper: Lama (Didja).

Naja melanoleuca – Chabanaud (1916): "Dahomey"; Villiers (1951): Abomey.

Naja nigricollis – Chabanaud (1916): "Dahomey"; Chabanaud (1917): Agouagon; Villiers (1951): Abomey; this paper: Lama Forest; Pendjari NP.

Naja senegalensis – Trape et al. (2009): Niénié.

Viperidae

Bitis arietans – Chabanaud (1916): "Dahomey"; Chabanaud (1917 b), Villiers (1951): Koussokoingou/Atakora, Zagnanado (as *B. lachesis*); this paper: Abomey; Bembéréké (ZFMK 72886).

Bitis nasicornis – Chabanaud (1916): "Dahomey".

Causus maculatus – Chabanaud (1916): "Dahomey" (as *C. rhombeatus*); Chabanaud (1917b): Agouagon (as *C. rhombeatus*); Villiers (1951): Koussokoingou/Atakora (as *C. rhombeatus*); this paper: Bohicon/Didja, Abomey.

Echis ocellatus – Chabanaud (1916): "Dahomey" (as *E. carinatus*); Chabanaud (1917 b): Agouagon (as *E. carinatus*); Villiers (1951): Koussokoingou/Atakora (as *E. carinatus*); this paper: Didja; Bembéréké (ZFMK 72867, 73091); Pendjari NP.

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Fitness components in the relationship between *Rhopalapion longirostre* (Olivier, 1807) (Insecta: Coleoptera: Apionidae) and *Alcea rosea* (Linnaeus, 1758) (Malvaceae). Analysis of infestation balance of a herbivorous weevil and its host plant

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Abstract. Multivariate statistics (principal components analysis, path analysis) were used to investigate fitness components of the interactions between the weevil *Rhopalapion longirostre* (Olivier, 1807), Apionidae, Coleoptera and its host plant *Alcea rosea* (Linnaeus, 1758), Malvaceae. We focused on the activities of the larvae such as the choice of seeds for consumption, the preparation of seed chambers as a site for pupation, as well as the construction of escape holes through which the adults later emerge.

The analyses revealed that the optimal conditions for successful development of the weevils depended on the availability of seed capsules characterized by a high number of well developed seeds, few undeveloped and few spoiled seeds. The high number of larvae, pupae and not emerged adults found in the seed capsules corresponds with the successful emergence of adults. Egg deposition by the females in appropriate flower buds of the host plant, together with larval contribution to overall reproductive success are important fitness components in the life cycle of the weevil. The reproductive success of the plant is partly guaranteed by a high number of seed chambers, many well developed seeds, many not infested seeds, and few undeveloped seeds. Furthermore, the extended blooming period of the host plant serves as an escape strategy by developing buds early or late in the season that cannot become entangled in the life cycle of *R. longirostre*.

Key words. *Alcea rosea,* Malvaceae, *Rhopalapion longirostre,* Apionidae; Host plant-parasite interaction, infestation balance, larval contribution, path analysis, PCA, reproductive success

INTRODUCTION

Life history theory provides a framework for analyzing the contribution of major features of the life cycle to reproductive fitness and seeks to place these features in an evolutionary context (Roff 1992; Stearns 1992; Stearns & Hoekstra 2000). The life history events of most of the 62,000 described species of weevils or snout beetles (Curculionoidea, Coleoptera) (Alonso-Zarazaga & Lyal 1999), and their immature stages are incompletely documented and more or less episodic. As holometabolous insects, weevils undergo a complete metamorphosis which produces larval and adult stages each with their own life habits and physiological and behavioral traits thus enhancing the possibility for adaptation, specialization and evolution. The phenomenal diversity of weevils was discussed recently in evolutionary terms by Oberprieler et al. (2007). Considered as a group, weevils utilize nearly all parts of host plants from almost all plant taxa (Anderson 1995).

The larvae of most Apionidae, with about 1800 described species (Kuschel 1995), feed internally in stems, leaves, buds, galls, fruits or seeds of their specific host plants. The evolution of larval habits and host plant associations are taken for analysis of larval role in weevil's diversification (Marvaldi et al. 2002).

In this paper we examine several fitness components of the weevil *Rhopalapion longirostre* (Olivier, 1807) which is monophagous on its host plant *Alcea rosea* (Linnaeus, 1758), with special focus on larval contribution to reproductive success (Reavey & Lawton 1991). Seeds of *A.*

rosea, presumably derived from Anatolia (Hammer 1994), were brought to France in the 18th century. The beauty and popularity of this garden plant, known as the hollyhock, passe-rose, rose trémière, or Stockrose, was lovingly recorded in verse by King Ludwig XVI of France in the 18th century: L'Amour de moi s'y est éclosé / dedans un petit jardinet, / où croit la rose et le muguet / et aussi bien la *passe-rose*.

Today, the plant occurs in many parts of Europe, North and South America, mainly due to its cultivation in gardens. The development of the larvae of *R. longirostre* takes place in the buds and seeds of *A. rosea* and the expansion of the weevil's distribution range has proceeded in intimate association with that of the host plant (Perrin 1995; Gønget 1997).

Females of *R. longirostre* have a body size from 2.4 to 3.4 mm excluding the rostrum (Freude et al. 1983). They employ their extremely elongated rostrum (average size 2.2 mm, standard deviation +/- 0.2 mm) (Wilhelm 2004), to bore holes into developing buds of *A. rosea*. The plant attains a height of 1 to 3 meters and can persist for more than two years. The buds appear in a long inflorescence composed of 30 to 50 buds. Every bud is surrounded by thick inner and outer sepals which have stiff grey-green hairs (Adler et al. 1994). After, or even during copulation, with the male sitting on her back, the female bores a channel into a selected bud using her rostrum. She turns around and inserts her ovipositor into the bore channel penetrating the outer and inner sepals of the plant to lay three to four eggs into it. Female weevils prefer to bore into buds located in the middle of the inflorescence. These buds will usually not bloom in the following 2 weeks thus allowing enough time for the development of the larvae. If a female is among the first to bore a hole into the bud, she chooses the side of the plant which receives the morning sunlight. If several females have oviposited in the same bud, the boring channels are widely spaced from each other, presumably to avoid competition among the larvae for food. The first instar larvae are legless, as most of weevils larvae have lost the development of legs (Crowson 1955; Stehr 1991; Marvaldi 1997; Farrell 1998), about 0.4 mm long, and they hatch after 3 to 4 days. If the bore channel is in the upper part of the bud then the larvae of the first stage consume the surrounding pollen grains. However, if the bore channel is located at the bottom side of the bud, then the larvae feed only on the soft tissue of the bud. All larvae bore feeding channels toward the direction of the ovules in the developing seed capsule, using their strong mandibles to bite and chew. By the time the bud has blossomed and before it falls off, all larvae must have migrated below the ovary. Within a few days the upper part of the blossom wilts and falls to the ground. When the seeds of *A. rosea* are fully developed, each larva tries to enter a seed chamber from the bottom of the seed capsule and consume the entire contents of the seed from within. Prior to pupation, the last instar bores a hole on the broadest side of the seed chamber to later escape when it reaches the adult stage. The escape hole is filled in with a secretion produced by the larva to protect the pupa and the developing weevil against outside influences, e.g. wetness and sunlight. Pupation lasts between 2 to 3 weeks depending on weather conditions. The darkening of the adult weevil's exoskeleton is visible through the transparent membrane of the pupa beginning at the apex of the rostrum and the elytra. The adult beetle slowly emerges from the dry and stiff seed chamber over a period of several hours using its rostrum to get out through the escape hole. A duration of 8 to 10 weeks is required from egg deposition to the emergence of adult weevils.

Additional details on the biology of *R. longirostre* are found in Dieckmann (1977), Behne (1998), Pupier (1997), Sprick et al. (2002) and Wilhelm (2004).

The interaction between the host plant and the weevil is reflected in a successful joint expansion in Europe over the last twenty years. To demonstrate this a null hypothesis was postulated which denied significant interactions between the life cycles of host plant and weevil. To test null hypothesis in detail, we posed the following questions:

(1) What parameters lead to optimal prerequisites for successful development of weevils in seed capsules? In particular, what are the conditions of capsules which contain larvae, pupae and immature adults? Do these conditions correspond with successful emergence of adults?

(2) Which counter strategies are taken by the host plant to survive or to ensure its successful growth and reproduction?

(3) How effective is larval contribution to the overall reproductive success of the weevil?

MATERIALS AND METHODS

To address these questions we examined dry seed capsules collected from 20 *Alcea rosea* plants growing on the terrace at the University of Vienna, Althanstrasse 14, in the first week of Nov. 2006. For measurements we examined only dry capsules (n=205) having a complete set of seed chambers. Seed capsules, which were incomplete because some seed chambers had already fallen to the ground, were not investigated. The plants, 1-20, contained the following number of seed capsules: 7, 10, 11, 4, 5, 6, 21, 4, 16, 8, 6, 11, 13, 24, 15, 13, 7, 9, 6, 9.

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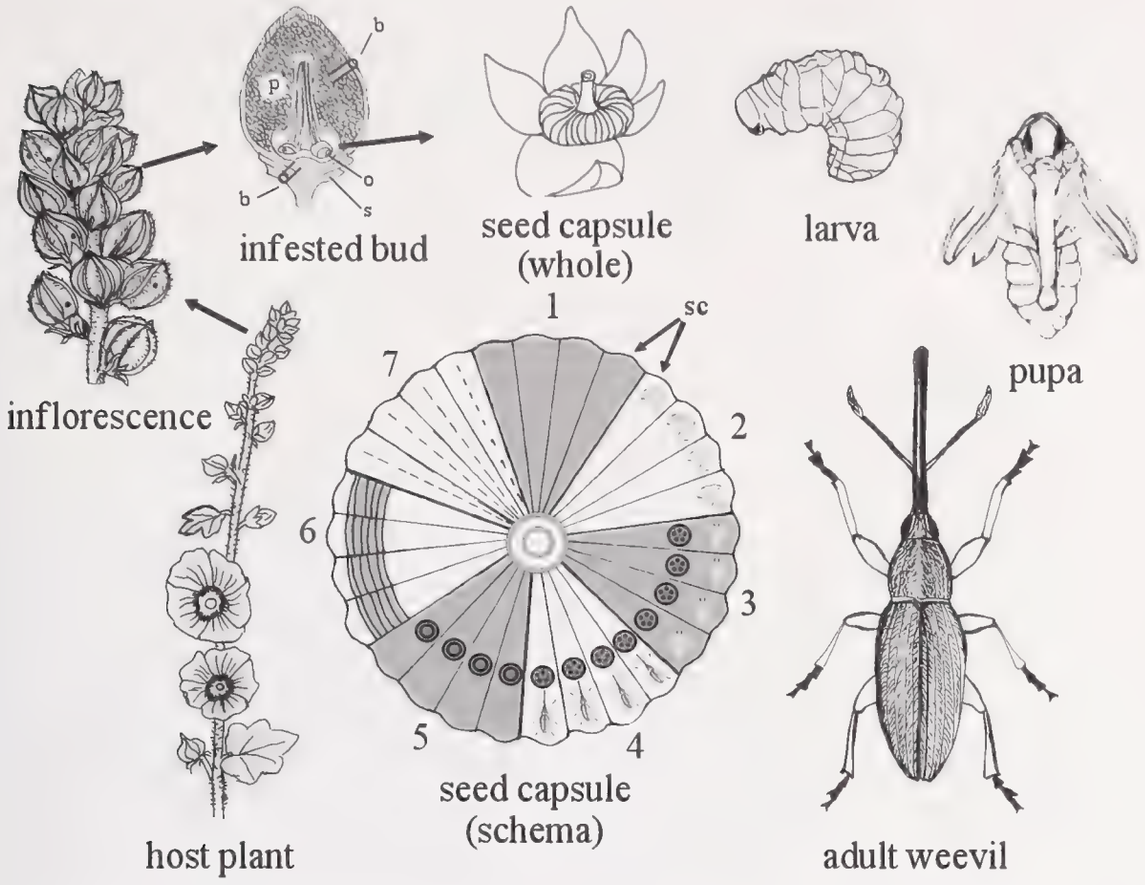

Fig. 1. Brief outline of life history stages of the weevil *Rhopalapion longirostre* on its host plant, *Alcea rosea*. Schema showing various conditions of a seed capsule: seed chambers with 1) fully developed seeds, 2) seeds infested with larvae, 3) pupae and closed escape holes, 4) not emerged adults and closed escape holes, 5) escape holes, 6) spoiled seeds, 7) undeveloped seeds. Abbreviations of infested bud: b bore channel, o ovules, p pollen, s sepal; sc seed chamber.

The diameter of each capsule was measured 5 times to cancel out error. The number of dry seeds per capsule and the condition of every capsule were documented. The seed chambers were opened under a dissecting microscope to determine the inner condition. The infested condition was indicated by the presence of larvae, pupae or not emerged adults, or empty seed chambers with open escape holes. The uninfested condition was indicated by the presence of seed chambers which are fully developed, undeveloped or spoiled. In the following, the data were analyzed thoroughly by multivariate statistics to estimate the importance of animal and plant related factors and their interactions on the reproductive fitness of weevil and plant.

For the following case study nine character variables of the seed capsules were measured for the statistical analyses.

Diameter of capsules in mm: **diam** (plant related: **PR**)

Number of seed chambers per capsule: **nrsc** (**PR**)

Number of open beetle escape holes per capsule: **nreh** (animal related: **AR**), i.e. estimate of the number of beetles which have successfully escaped.

Number of dead larvae per capsule: **nrla** (**AR**)

Number of dead pupae per capsule: **nrpu** (**AR**)

Number of dead, not emerged adults per capsule: **nrne** (**AR**)

Number of fully developed seeds per capsule: **nrds** (**PR**)

Number of undeveloped seeds per capsule: **nrus** (**PR**)

Number of spoiled seeds per capsule: **nrss** (**PR**)

In preparation of multivariate analyses, the original data were transformed as follows: The first variate was logarithmically transformed (natural log). In order to fulfill the

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Table 1. Correlation matrix of transformed variates and significant levels: *** = highest significant P-value ≤ 0.001, ** = highly significant P-value ≤ 0.01, * = significant P-value ≤ 0.05. Bonferroni corrected. Variates: **diam** diameter of seed capsule, **nrsc** number of seed capsules, **nreh** number of escape holes, **nrla** number of larvae, **nrpu** number of pupae, **nrne** number of not emerged adults, **nrds** number of fully developed seeds, **nrus** number of undeveloped seeds, **nrss** number of spoiled seeds. The significance of correlation coefficients was determined by a random permutational test (Nemeschkal 1999).

	diam	**nrsc**	**nreh**	**nrla**	**nrpu**	**nrne**	**nrds**	**nrus**	**nrss**
diam	1.0000								
nrsc	0.075632	1.0000							
nreh	0.057043	0.167632*	1.0000						
nrla	0.032532	0.293509***	- 0.135968	1.0000					
nrpu	0.013449	0.280319***	- 0.044457	0.538041***	1.0000				
nrne	- 0.07478	0.129488	0.128997	0.161018	0.212016***	1.0000			
nrds	0.036070	- 0.046134	- 0.247253***	- 0.304999***	- 0.31991***	- 2.242189***	1.0000		
nrus	0.000937	0.163294	- 0.257581***	- 0.028526	- 0.088356	- 0.046297	- 0.306250***	1.0000	
nrss	- 0.001917	0.254107***	- 0.267961***	0.096727	0.208869**	0.088184	- 0.402289***	0.165270*	1.0000

Table 2. Factor matrix, axis 1 to 7, and significant axes of loadings. *** = highest significant, P-value ≤ 0.001, ** = highly significant P-value ≤ 0.01, * = significant P-value ≤ 0.05, ns= no significance P-value > 0.05, eigenvalues, and percentages of the total variance. The significant levels were determined by a random permutational test (NEMESCHKAL 1999, 10000 iterations). Potential win for animal and plant. + A, + P; potential loss: - A, - P. Abbreviations of axes: **SUPLA** for ´successful plant (seed) production´; **SUAN for** ´successful animal production´; **SUMIX** for ´integration of the two trends, successful animal and plant production´; **LIFA** for ´late infestation axis´ and **DASA** for ´damaged seed and animal axis´.

Factor axes	F1	F2	F3	F4	F5	F6	F7
Abbreviations	**SUPLA**	**SUAN**	**SUMIX**	**LIFA**	**DASA**	**n.n.**	**n.n.**
var 3 nreh	- 0.083229ns	- 0.723916***	0.568846***	- 0.237805**	0.174577ns	- 0.024872ns	0.240388***
var 4 nrla	0.680778***	- 0.168066*	- 0.463831***	- 0.297076***	- 0.174923ns	0.394877***	0.135561ns
var 5 nrpu	0.726492***	- 0.245330***	- 0.380804***	- 0.114225ns	0.074140ns	- 0.498353***	0.010510ns
var 6 nrne	0.430808***	- 0.379749***	0.211681***	0.631854***	- 0.475213***	0.012534ns	0.012746ns
var 7 nrds	- 0.743359***	0.012772ns	- 0.532765***	0.217806**	- 0.116773ns	- 0.103023ns	0.302864***
var 8 nrus	0.217084**	0.687623***	0.397469***	- 0.274868***	- 0.443069***	- 0.147826ns	0.168382ns
var9 nrss	0.559095***	0.458271***	0.118490ns	0.384199***	0.525592***	0.073805ns	0.184544**
Eigenvalues	2.096067	1.439697	1.184405	0.827693	0.778592	0.442973	0.230572
percentage of total variance	29.94	20.57	16.92	11.82	11.12	6.33	3.29
animal win/loss	-A	+A	+A	+A	-A		
Plant win/loss	+P	-P	+P	+P	-P		

linearity requirement, variates 2 to 9 were substituted by their square roots. Finally, a product moment correlation matrix was calculated between all variates over the 205 capsules (Table 1).

The correlation structure of variates 3 to 9 was then analyzed by a principal components analysis (PCA, for details see Morrison 2004). An orthogonalization was reached via PCA by calculating a full analysis and extracting all possible, i.e. 7, axes (Stat. Graphics – Version 7.3 for MS DOS). The eigenvectors were scaled according to eigenvalues leading to a factor matrix (Table 2). The significance of loadings on principle axes was determined by a random permutational test, 10000 random permutations each, (Nemeschkal 1999). Note that the original variates are represented on factor axes by their loadings. A loading is the product moment correlation of an original variate with the factor axis. For details and further statistical explanation, see Morrison (2004).

Path analysis, a special type of regression analysis, (Stat. Graphics – Version 7.3 for MS DOS) was applied to rep-

resent the complicated animal-plant relations in diagrammatic form (Path diagrams, Figs. 2 and 3). In addition, path analysis has the advantageous option to focus dependencies either on plant or for animal variables (for theoretical details on path analysis, see Sokal & Rohlf (1995).

For reasons of simplicity, our analyses are mainly based on procedures of the general linear model. In order to test whether a loss of information in the data structure has occurred due to data transformations, we calculated, in parallel log-linear analyses with the non-transformed data (see Appendix).

RESULTS

Of the 205 examined seed capsules, each contained an average of 35 individual seed chambers (ll 34.7758, ul 35.6798; ll: lower limit, ul: upper limit of 95% confidence of average). Of the 35 seeds chambers, an average of 13 (ll 11.6393, ul 13.4734) were fully developed, inferring the reproductive success of the host plant, 7 (ll 6.0002, ul 7.6396) had open escape holes, inferring the potential reproductive success of the weevils. The remaining 15 seed chambers (on average per capsule) were either infested (documented by dead larvae, pupae or not emerged adults), undeveloped or spoiled by mold or mites.

The results from the PCA and the path analyses reveal detailed information on the complex system of interactions between weevil and host plant. For the sake of simplification, the diameter and number of seed chambers were omitted from the PCA and path analyses since the simple correlation between the diameter (diam) and the remaining variates are not significant (Table 1) and since the number of seed chambers (nrsc) is a summation of variates 3 to 9.

A total of 7 axes are significant (Table 2). Factor axes 1 to 5 are the most important, accounting for over 90% of the total variance.

Results summarized for the five most important factor axes:

F1 represents nearly 30% of total variance. Positive and negative signs of the loadings indicate the reverse proportionality in the variational trends: nrla, nrpu, nrne, nrss (positive and very highly significant) and nrus (highly significant) versus nrds (negative and very highly significant).

F2 represents 21% of total variance. Cumulatively, the axes F1 and F2 explain half of the total variance. The loadings are contrasted to each other by their signs (+/-); i.e. nrus and nrss (very highly significant) and with positive signs, versus nreh, nrpu, nrne (very highly significant) and nrla (significant), both with negative signs.

F3 explains 17% of the total variance, and by accumulation of axis F1 to F3 more than two thirds of total variance are explained. The signs of loadings, nreh, nrne and nrus (very highly significant) contrast with those of nrla and nrpu (very highly significant).

F4 represents about 12% of total variance. Axes F1 to F4 cumulatively explain more than three quarters of total variance. The loadings are grouped by positive signs for nrne, nrss (very highly significant) and nrds (highly significant) and negative signs for nrla, nrus (very highly significant) and nreh (highly significant).

F5 explains 11% of total variance. The positive sign of the loading nrss (very highly significant) contrasts with those of nrne and nrus (very highly significant).

Factor axes 6 and 7 together provide 9% of total information and will not be further considered in this study.

Path Analyses

Two path analyses were conducted to focus on the main influences affecting the animal's or plant's life cycle. Variables 3 to 9 served as the basis for both path analyses. The first analysis determines the influence of variables 4 to 9 on variable 3 (nreh: number of escape holes per capsule, AR = animal related) (Fig. 2). In the second analysis variable 7 (nrds: number of fully developed seeds per capsule, PR = plant related) the variables 3 to 6, 8 and 9 take influence on variable 7 (Fig. 3).

Path Analysis I (Fig. 2): Since variable 3, nreh, number of escape holes per capsule, may be an indicator of fitness for the weevil, it was subjected to a multivariate path analysis. Simple arrows indicate the directions of influences of the predictors on criterion (= direct paths), double arrows indicate the correlation between predictor variables. The strength of influence is given by the value of the path coefficient. The path coefficient is a standardized multiple regression coefficient (path coefficient = regression coefficient times standard deviation of predictor divided by the standard deviation of criterion). The path coefficient quantifies the amount of change in criterion when progressing in independent variables. There are 4 direct paths from the predictors to the criterion. The first direct path proceeds from var 4, nrla, to the criterion and is negative and highly significant. It infers that the more dead larvae per capsule, the fewer escape holes. The second direct path from var 7, nrds, to the criterion is negative and very highly significant: the more well developed seeds, the fewer open escape holes. The third direct path proceeds

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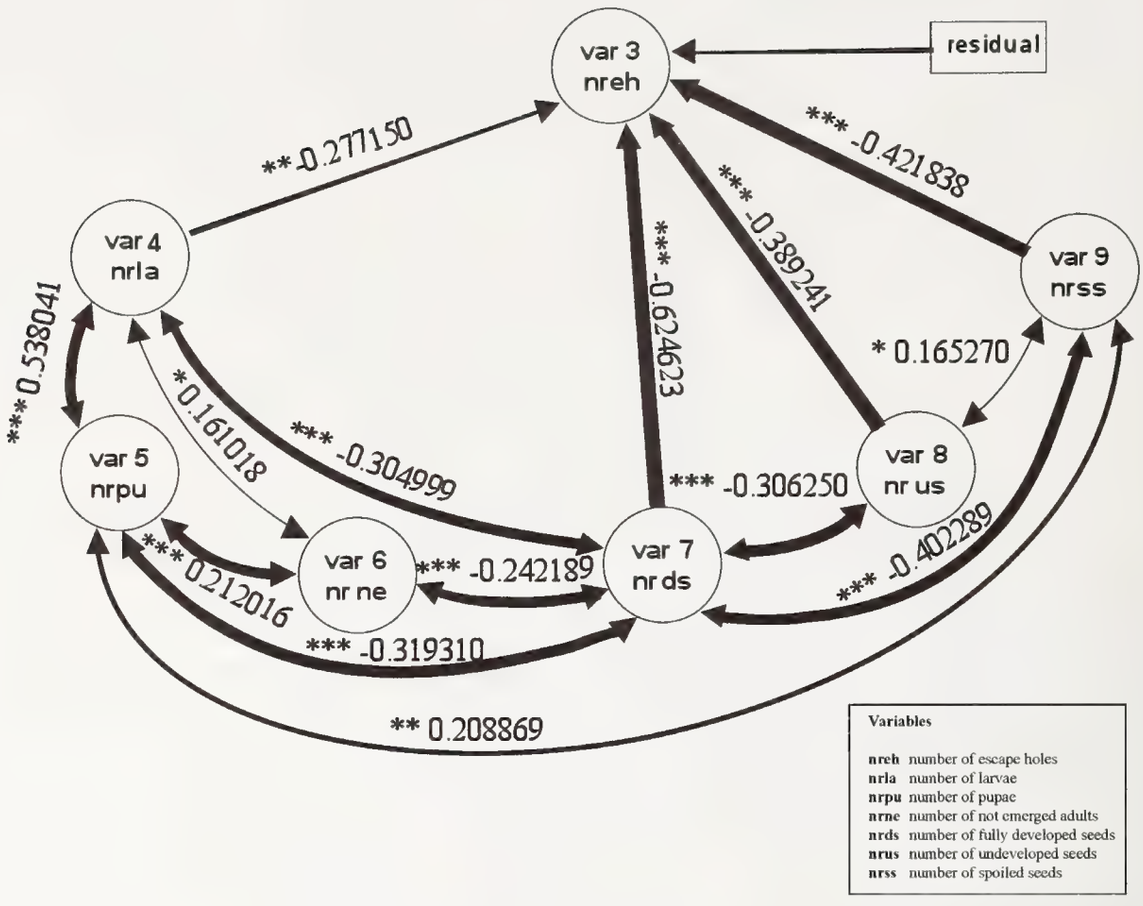

Fig. 2. Path diagram 1 showing 6 predictor variables and a residual effecting one criterion (var 3, nreh, number of escape holes, an animal related variate), R^2= 0.414525. The path diagram explains 41.45% of the variance of the criterion. Only significant paths are shown. The significance of paths was determined by random permutational test; 10000 iterations each; Bonferroni Correction. Simple arrows indicate the direction of influences of the predictors to the criterion (= direct paths), double arrows indicate the correlation between predictor variables. The strength of influence is given by the value of the path coefficient.

from var 8, nrus, to the criterion and is negative and very highly significant: the more undeveloped seeds, the fewer escape holes. The fourth direct path proceeds from var 9, nrss, to the criterion and is negative and very highly significant: the more spoiled seeds per capsule, the fewer open escape holes. In addition, several indirect effects are apparent. Both direct and indirect paths in the diagram must be combined to indicate an overall influence on the criterion. The most important indirect path proceeds from nrla to the criterion via nrds, and is very highly significant: the more larvae, the fewer well developed seeds and the more escape holes (indirect effect: -0.304999 * -0.624623 = 0.190509). Direct and indirect paths are mutually counteracting, therefore it is the summation of all effects that indicates the overall influence on the criterion, which in this case is negative: direct effect: nrla → nreh -0.277150 plus indirect effect: nrla → nrds → nreh 0.190509 results in an overall effect of -0.086641. A second indirect effect proceeds from nrla to the criterion via nrpu, nrne and nrds: the more larvae, the more pupae and the more not emerged adults means that there are fewer well developed seeds and more escape holes in the seed capsule (0.538041 * 0.212016 * -0.242189 * -0.624623 = 0.017257). Another indirect effect between nrpu and nrds to the criterion is very highly significant: the more pupae, the fewer well developed seeds and the more escape holes (-0.31931* -0.624623 = 0.19945). The indirect effect which proceeds from nrds and nrus to the criterion is very highly significant: the more developed seeds, the fewer undeveloped seeds and the more escape holes (-0.30625) * -0.389241 = 0.11921. The indirect effect which proceeds from nrds and nrss to the criterion is very highly significant: the more developed seeds, the fewer spoiled seeds and the more escape holes (-0.402289 * -0.421838 = 0.1697). Overall, the indirect effects indicate a decrease of the negative influence from the direct paths to the criterion.

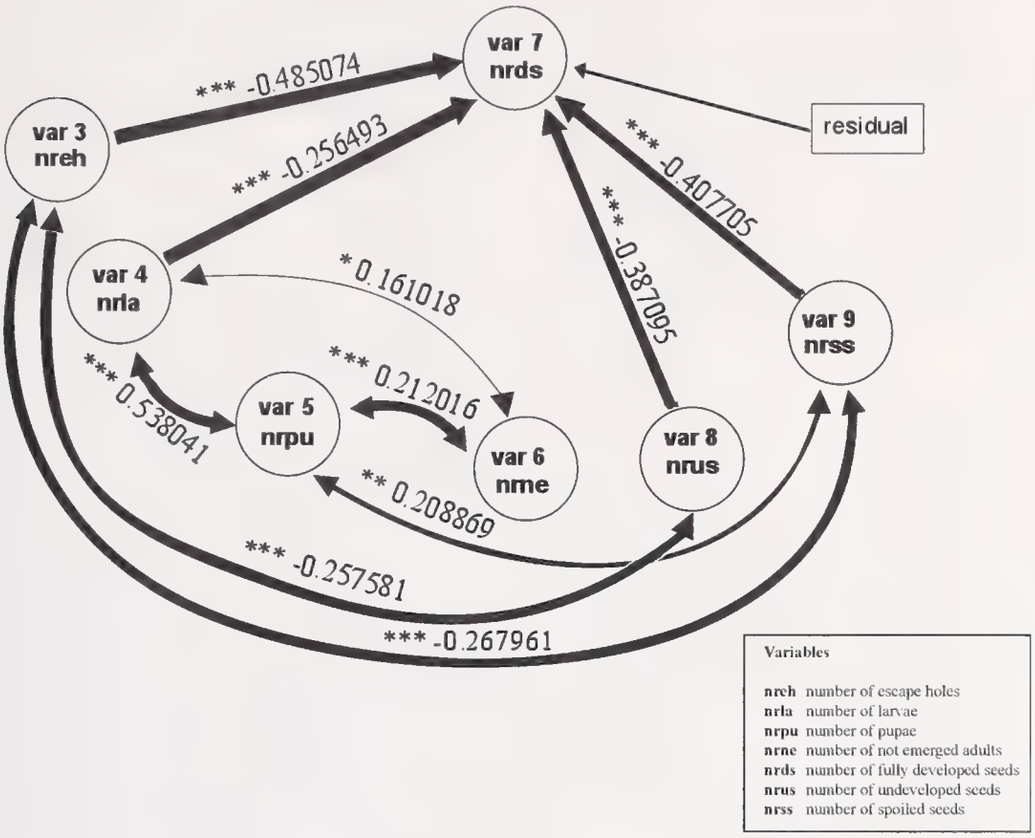

Fig. 3. Path diagram 2 showing 6 predictor variables and a residual effecting on criterion (var 7, nrds, plant related variate, number of fully developed seeds per seed capsule), $R^2 = 0.545329$. The path diagram explains 54.53% of the variance of the criterion. The significance of paths was determined by random permutational test, 10000 iterations each, Bonferroni Correction.

Path Analysis II (Fig. 3): The second path analysis, using the same variables as in the first analysis, was calculated to determine the influence of variables 3–6, 8 and 9 on variable 7, nrds, number of fully developed seeds per capsule, which is the most important plant related factor. Since variable 7 may be an indicator of fitness for the plant, it was subjected to a multivariate path analysis.

There are 4 direct paths from the predictors to the criterion. The first direct path proceeds from var 3, nreh, to the criterion and is negative and very highly significant: the more escape holes, the less fully developed seeds per capsule. The second direct path from var 4, nrla, to the criterion is also negative and very highly significant: the more larvae, the fewer well developed seeds. The third direct path, from var 8, nrus, to the criterion is negative and very highly significant: the more undeveloped seeds, the fewer developed seeds per capsule. The fourth direct path, from var 9, nrss, to the criterion is also negative and very highly significant: the more spoiled seeds, the fewer well developed seeds.

There are several indirect effects between the predictors and the criterion. The indirect effect proceeds from var 3 and var 8 to the criterion and is very highly significant: the more escape holes, the less undeveloped seeds and the more fully developed seeds (-0.257581 * -0.387095 = 0.09971). The indirect effect between nreh and the criterion, via nrss, is very highly significant: the more escape holes, the fewer spoiled seeds and the more fully developed seeds (-0.267961 * -0.407705 = 0.10925). Both paths show a decrease of the negative influence of escape holes on the criterion. Another indirect effect from nrne, via nrpu, via nrla to the criterion is very highly significant: the more not emerged adults, the more pupae and the more larvae, the fewer well developed seeds will be found (0.212016 * 0.538041* -0.256493 = -029259). This indirect effect shows a negative influence on the criterion.

In summary, both the PCA and the path analyses explain animal - plant interactions; path diagram 1 focuses on the animal, while path diagram 2 centers on the plant.

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Discussion

The relationships between insects and plants are of utmost importance for terrestrial global ecology. Many of these relationships involve specialized herbivorous insects and their host plants on which the females oviposit and on which the larvae feed (Schoonhoven et al. 1998). The choice of an oviposition site is instrumental for the fitness of many weevils (Messina 2004). In a case study approach we investigated fitness components of the interactions between the weevil, *R. longirostre* and its host plant, *A. rosea*.

The life cycles of the weevil and its host plant must be considered in connection with each other. With the help of multivariate statistics it was possible to isolate several main factors which contribute toward the survival of the host plant, as well as the successful development of the weevil. The lengthy inflorescence of *A. rosea* may contain of more than 30 buds in different development stages ranging from fully developed buds at the bottom, which will blossom soon, to immature tiny buds at the top. Host plant preferences of the female weevils for oviposition sites are buds located in the middle of the inflorescence. Exactly these offsetting development stages of the buds are reflected in the PCA (Table 2). In summary, the PCA provides an overview of the interaction system between the plant and the weevil.

Factor axis 1, which is the most important one, is interpreted as the axis which reflects successful seed development: The variate of final production outcome in the plant, i.e. nrds, number of developed seeds, is contrasted to the counteracting variables of numbers of undeveloped seeds, nrus, and spoiled seeds, nrss, and indicators of weevil development, nrla, nrpu and nrne. The axis is to be read as follows: the more developed seeds, the less dead larvae, pupae and not emerged adults in the capsules but also the less undeveloped and spoiled seeds. In contrast to this interpretation, axis 1 could be read as: the more dead larvae, pupae and not emerged adults inside the capsules and the more undeveloped and spoiled seeds, the less developed seeds. Note that the variable of plant final success, nrds, is exclusively represented on axis 1 but not the variable of the animal final success, nreh. Consequently, we assigned to axis 1 the abbreviation SUPLA for "successful plant" (i.e. seed) production.

The next most important axis, factor axis 2, is to be interpreted as mainly reflecting weevil development and production. The variate of final production outcome in the animal, i.e. nreh, number of escape holes, is combined in variation with the variates of animal development, i.e. nrla, nrpu, and nrne. Whereas the first variate, nreh, signifies production success, the remaining variates nrla, nrpu and nrne stand for the unsuccessful weevil development in the host plant. However, all the animal related variates are contrasted to plant variates which stand for unsuccessful seed development, i.e. nrus and nrss – undeveloped and spoiled seeds. The axis loading read as: The less undeveloped and spoiled seeds, the more escape holes but also the more dead larvae, pupae and not emerged adults. Note that the variate of final production outcome in the plant, nrds, is not significantly represented on this axis. Consequently, we designate this axis SUAN, "successful animal" production, as a main infestation axis. Highly infested capsules were located in the middle of the plant's inflorescence. Early infestation of seed capsules guarantees high reproductive success for the weevil as shown by the high proportion of open escape holes. In cases where a high number of seeds were infested, the number of undeveloped and spoiled seeds was very low.

Factor axis 3 reflects the mutual interaction of weevils and plant production. In one group of variates the final production outcome of the animal, nreh, and the pre-developmental stage to that final outcome, i.e. nrne, are combined with the number of undeveloped seeds. In contrast, in the second group of variates, the final production outcome of the plant, nrds, is combined with the developmental variates of the weevil, nrla and nrpu. The axis loadings can be read in two different ways, both immediately indicating a competitive race between animal and plant to maximize their fitness (as shown for a seed predatory weevil and its host plant, Toju, Sota 2006). On the one hand, the more escape holes, as well as not emerged adults and undeveloped seeds in capsules, infer fewer developed seeds, as well as larvae and pupae. On the other hand, the more developed seeds, as well as larvae and pupae, infer fewer escape holes, not emerged adults and undeveloped seeds. There are two counter acting trends: One, early infestation by the weevil which is characterized by a high number of open escape holes and not emerged adults together with a high number of undeveloped seeds. Since larvae only infest well developed seeds, few seeds remain for plant development. The second trend concerns late infestation and incomplete weevil development. It is characterized by a high number of larvae and pupae together with a high number of developed seeds. The abbreviation SUMIX (successful animal and plant production) represents the integration of the two trends.

Factor axis 4 can be interpreted as late infestation. Both variates, nrds and nreh, are highly significant and contrast each other. In the one group of variates, nrds is combined with nrss and nrne. In another group, nreh is combined with nrla and nrus. The variate loadings are interpreted as the following: many developed seeds and many spoiled seeds infer few undeveloped seeds in capsules, while the presence of fewer escape holes and fewer larvae infer

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more not emerged adults. A high number of spoiled seeds indicates that adverse weather conditions, mostly in late summer, could have influenced negatively both seed and weevil development, and in particular, the escape of adult weevils. We abbreviate this axis LIFA, "late infestation axis".

Factor axis 5 is an axis representing damaged seeds and late developmental stages of the weevils. The variate, nrss, contrasts with nrus and nrne. The loadings are interpreted as follows: The presence of many spoiled seeds infers fewer undeveloped seeds and fewer not emerged adults, and vice versa. This axis is termed DASA, "damaged seed and animal axis".

The main important axes of the PCA provide a comprehensive explanation about the complex system of interaction between animal and plant.

The influences and trends of both path diagrams must be seen in the light of direct paths and indirect effects (see Figs. 2 and 3). Our null-hypothesis was falsified by the significant correspondence between the life cycle of host plant and weevil. In path diagram 1, all direct paths (without exceptions) from the different variates to the criterion have strong negative influences. The sequence of indirect effects between the number of larvae → number of well developed seeds → criterion, as well as the indirect influence nrla → nrpu → nrne → nrds → criterion, nreh, are very important. As larval feeding habits are highly conservative some of these habits are apparently irreversible, e.g. feeding on seeds (Marvaldi et al. 2002). Larvae of the last developmental stage choose well developed seeds to enter, to consume and to prepare the seed chamber for pupation and future escape. The sequence of indirect effects, nrds → nrus → criterion, or nrds → nrss → criterion, are also very important. For the performance of a larva, it is vital to find a well developed seed instead of an undeveloped or spoiled seed.

In path diagram 2, the 4 direct paths (without exceptions) have also strong negative influences on the criterion nrds. The indirect effects are advantageous for both, plant and animal production. The sequence, nrne → nrpu → nrla → criterion, indicates that the high number of infested seeds are based on a high number of formerly well developed seeds. The sequences, nreh → nrus → criterion, nrds, and nreh → nrss → nrds, infer that high numbers of escape holes and few undeveloped or spoiled seeds increase the number of well developed seeds. A plant in a healthy condition guarantees the performance of the weevils. The time of infestation is crucial for the weevils. Our analyses reveal that an infestation occurring late in the season involves a high likelihood of poor plant condition, as shown in the indirect effect nrpu → nrss → nreh.

In conclusion, we address the initial questions posed in the introduction.

1) What are the optimal conditions for the reproduction of weevils? The most important optimal condition for weevil reproduction is the timely presence of many well developed seeds.

2) What are the optimal conditions for the successful development of plants? The optimal conditions for the successful development of plants are few undeveloped and few spoiled seeds.

3) Is the contribution of larvae to the overall reproductive success of the weevils important?

Yes, in both path diagrams, the animal related variate, i.e. number of larvae, has a highly significant direct path to the first criterion, number of escape holes, as well as to the second criterion, well developed seeds. Obviously larvae benefit from capsules with a very high number of well developed seeds. Since the number of larvae has an exclusively direct impact on both criteria, this influence is interpreted as a high larval contribution to the reproductive success of *R. longirostre*.

Our results strongly support the view of an intricate relationship between the life cycles of *A. rosea* and *R. longirostre*. The plants' period of bud development lasts from April to October. The weevils utilize a window within this range to fulfill their development, beginning in May after hibernation in the soil and ending in September with the completion of their life cycle and the emergence of the next adult generation from the seed chambers. The time periods before and after weevil activity ensure enough opportunity for successful production of seeds.

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APPENDIX

Poisson regression analysis

Dependent variate: nreh

Regression coefficients (predictors):

beta- 0 (constant):	4.632211	< 0.0001	
beta- 1 (nrla):	-0.170142	0.0002	***
beta- 2 (nrpu):	-0.040228	0.4612	n.s.
beta- 3 (nrne):	0.040783	0.5624	n.s.
beta- 4 (nrds):	-0.405291	< 0.0001	***
beta- 5 (nrus):	-0.267374	< 0.0001	***
beta- 6 (nrss):	-0.258430	< 0.0001	***

global model, deviance: 530.341739, P-value = < 0.0001, ***

The significance was tested by random permutational tests (10000 iterations each).

Dependent variate: nrds

Regression coefficients (predictors):

beta- 0 (constant):	3.797212	< 0.0001	
beta- 1 (nreh):	-0.166088	< 0.0001	***
beta- 2 (nrla):	-0.098854	0.0072	**
beta- 3 (nrpu):	-0.061230	0.1904	n.s.
beta- 4 (nrne):	-0.079595	0.1760	n.s.
beta- 5 (nrus):	-0.158951	< 0.0001	***
beta- 6 (nrss):	-0.170892	< 0.0001	***

global model, deviance: 340.101076, P-value = < 0.0001 ***

The significance was tested by random permutational tests (10000 iterations each).

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Life-history of *Gnopharmia kasrunensis* Wehrli, 1939 and *G. colchidaria* Lederer, 1870 (Geometridae, Ennominae) and their distribution in Iran, with first host-plant records for the genus

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Abstract. For the first time, observations on the life-history of the little known species *Gnopharmia kasrunensis* Wehrli, 1939 and *G. colchidaria* Lederer, 1870 are reported; eggs, larvae, pupae, adults and habitats are illustrated. Suitable differential features for a correct identification of both Iranian *Gnopharmia* species as well as a distribution map are provided.

Zusammenfassung. Erstmals wird über Beobachtungen zur Biologie der wenig bekannten Arten *Gnopharmia kasrunensis* Wehrli, 1939 und *G. colchidaria* Lederer, 1870 berichtet. Eier, Larven, Puppen, Imagines und ihre Lebensräume werden beschrieben. Für die korrekte Bestimmung der beiden iranischen *Gnopharmia*-Arten werden geeignete differentialdiagnostische Merkmale sowie eine Verbreitungskarte vorgelegt.

Key words. *Gnopharmia kasrunensis, colchidaria*, biology, distribution, Iran

INTRODUCTION

The genus *Gnopharmia* Staudinger, 1892 belongs to the tribe Macariini (Ennominae) (Wehrli, 1953: 565; Scoble & Krüger 2002) and consists of several species which are difficult to determine by external means only. Parsons et al. (1999) list thirteen species in this genus. At present, *Gnopharmia* is in the process of taxonomic revision by the author. By discovery of one new species and five synonymies, the number of valid species in the genus has been reduced to nine. All species occur in the Middle East and Asia Minor, their geographic range extending from Turkey to Pakistan. Five of the species occur in Iran. Our present knowledge on the biology and distribution of *Gnopharmia* species is very poor, partly due to difficulties of their correct identification. In the original descriptions of species in this genus (e.g. Ebert 1965, Erschoff 1874, Lederer 1870, Staudinger 1892, Wehrli 1938, Wehrli 1939, Wehrli 1941, Wiltshire 1967, Wiltshire 1970) no host plant records or notes about their biology are given. Prout (1915) listed three *Gnopharmia* species and six subspecies, and Wehrli (1953) mentioned seven species (and 11 subspecies). Both described the external features and Wehrli also characters of their genitalia, but they did not mention host plants or larval stages. The host-plant index published by The Natural History Museum, London (HOSTS, 2007), also does not record any host plant for species of the genus *Gnopharmia*.

After a number of unsuccessful breeding experiments with *Prunus* spp. and other Rosaceae species by various lepidopterists, the first correct suggestion about the host plant of *Gnopharmia* was made by Bernd Müller (Berlin; pers. comm.), who assumed the wild Almond which occurs abundant in the habitats where *Gnopharmia* species occurs (*Prunus*, subgenus *Amygdalus*; Rosaceae). The first breeding of a *Gnopharmia* was made by Robert Trusch (Karlsruhe; pers. comm.) in 2008 with material from East-Iran (Prov. Ostān-e Khorāsān, Birjand, Kuh-e Mirza Arab, 2.040 m a.s.l); larvae were fed with leafs of wild Almond shrubs from the field in Iran, but the experiment had to be finished because of the lack plant material in Germany; the species of the reared larvae remained undetermined

During May and July 2009, the author collected females of *G. kasrunensis* (Fig. 13) and *G. colchidaria* (Fig. 14) at several localities in Iran. The present paper illustrates the larval stages of both species and gives an overview of their distribution.

MATERIAL AND METHOD

Females of *Gnopharmia* species have been collected at six Localities (Table 1) by using a light trap. For laying eggs,

they were caged inside small plastic boxes with tissue paper, eventually adding suitable plant material.

In Tole-Heidari valley (province Fars, south of Jahrom, N 28°28'56" E 053°23'09", altitude 1112 m a.s.l.) May 15, 2009, one female of *G. kasrunensis* has been collected (culture A, table 1). This habitat is very dry and there are scattered bushes of different plant species. *Prunus lycioides* (Rosaceae; det. H. Akhani and M. Yazbek) as a possible host plant is common. Three females of *G. kasrunensis* were found in Ras-Kuh (province Kerman, road Baft-Sirjan, 2 km after Baft, N 29°17'27" E 056°35'37", altitude 2540 m a.s.l.) May 20 to May 21, 2009 (cultures B, C and D, table 1). This locality near Ras-Kuh village has a southeast-facing aspect (Fig. 1). The dominant plant species in the area is *Prunus scoparia* (det. H. Akhani and M. Yazbek) (Fig. 3 and 4). Material of this plant species has been added to the plastic boxes containing females. Two females of *G. colchidaria* have been collected at the mountains near the village Ab-Asemani, (province Fars, road from Estahban to Sarvestan, 20 km to Sarvestan, N 29°05'51" E 053°26'12", 1890 m a.s.l., May 22, 2009) (cultures E and F, table 1). This biotope has a northern exposure. *Prunus scoparia* was common here too, but there also were wild *Pistacia* trees (Anacardiaceae), many bushes of *Astragalus* (Fabaceae) and *Echinops* (Asteraceae), and several *Umbelliferae* spp. (*Umbelliferae*) (Fig. 2).

One female of *G. colchidaria* has been collected at Oshtorankuh (province Lorestan, between Dorud and Gahar lake, near Cheshmeh-Khorram, N 33°22'41" E 049°11'13 '', 2360 m a.s.l., Jun 22, 2009 (culture G, table 1). Five females of *G. colchidaria* were found at Gardaneh-Garrin (province Hamadan, 25 km to Nahavand from Noorabad, N 34°02'48" E 048°20'31", 2135 m a.s.l., Jun 25, 2009 (cultures H–L table 1) and at Khani-Sefid in Gardaneh-Khan near the border of Iran-Iraq (province Kordestan, 10 km from Saghez to Baneh, N 36°04'13" E 045°59'31", altitude 1976 m a.s.l., June 26, 2009) one female of *G. colchidaria* has been collected (culture M, table 1). No eggs or larvae have been observed in nature. Pupation of *G. kasrunensis* larvae (culture C) took place in the field (Iran), that of *G. colchidaria* (culture F) in the laboratory in Karlsruhe-Germany. In the field, the study of egg-morphology was done using a hand lens.

For this study the species have been identified by using male genitalia of freshly emerged adults. Identifying females by their genitalia is still problematic, as differences between species are minute and not fully understood at present. In some cases (e.g. *G. colchidaria*) only a female emerged and for identification genitalia dissection of simultaneously collected males were used. There are clear characters in the male genitalia, especially in the aedeagus, that can be used to separate the species. The aedeagus of *G. kasrunensis* is thicker and shorter (length 1.2–1.5 mm) than that of *G. colchidaria* (length 1.4–1.8 mm) and bears a group of 2–6 long, rod-like, subapical spines (length up to 0.3 mm) with rounded tip (Figs 24, 28). In contrast, the aedeagus of *G. colchidaria* has a subapical group of short, more or less cone-shaped spines (maximum 0.15 mm in length), 1–3 of them situated more distally and 2–3 (rarely up to 5) more basally (Figs 25, 29).

The tips of the 'octavals' (a pair of distal processes at sternite 8) are more strongly curved in *G. kasrunensis* (Figs 22, 26), than in *G. colchidaria* (Figs 23, 27). The genitalia capsules of both species are similar in size and shape,

Table 1. Species, date and number of collected females and their eggs, larvae and pupa, and dates of hatching and pupation, according to cultures.

Code of culture	Species	Date of collecting	Date of laying egg	N. eggs	Date of hatching	N. larvae	Date of pupation	N. pupa
A (loc. 1)	*G. kasrunensis*	15.5.09	17.5.09	27	21.–22.5.09	21	–	0
B (loc. 2)	*G. kasrunensis*	20.5.09	23.–24.5.09	37	27.–28.5.09	28	–	0
C (loc. 2)	*G. kasrunensis*	20.5.09	23.–24.5.09	14	27.–28.5.09	12	25.6.09	1
D (loc. 2)	*G. kasrunensis*	21.5.09	24.–25.5.09	28	28.–29.5.09	22	–	0
E (loc. 3)	*G. colchidaria*	22.5.09	28.–29.5.09	24	30.–31.6.09	17	–	0
F (loc. 3)	*G. colchidaria*	22.5.09	28.–29.5.09	33	30.–31.6.09	21	2.7.09	1
G (loc. 4)	*G. colchidaria*	22.6.09	25.6.09	18	29.–30.6.09	16	–	0
H (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	16	1.–2.7.09	16	–	0
I (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	45	1.–2.7.09	36	–	0
J (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	42	1.–2.7.09	38	–	0
K (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	17	1.–2.7.09	14	–	0
L (loc. 5)	*G. colchidaria*	25.6.09	27.–28.09	40	1.–2.7.09	36	–	0
M(loc. 6)	*G. colchidaria*	26.6.09	28.–29.6.09	9	2.–3.7.09	7	–	0

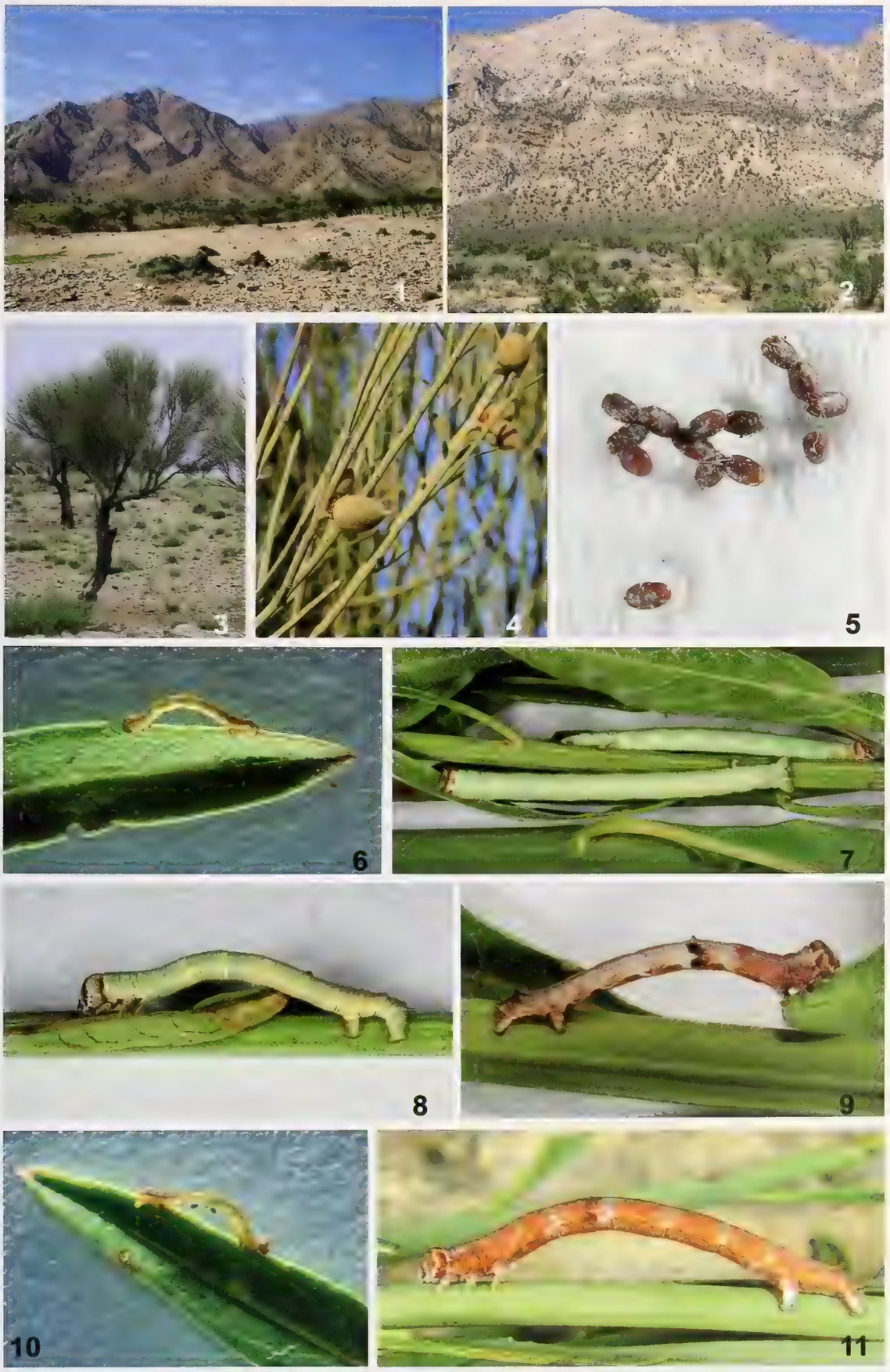

Plate 1. Figs 1–2: Biotopes of *Gnopharmia* species: 1, *G. kasrunensis* (Ras-Kuh, cultures B, C and D); 2, *G. colchidaria* (Ab-Asemani village, cultures E and f); Figs 3–4: host-plant: 3, tree of *Prunus scoparia*; 4, leaves and fruits of *Prunus scoparia*; Fig. 5: eggs of *G. kasrunensis* (culture C); Figs 6–8: larvae of *G. kasrunensis:* 6, L2; 7, L4; 8, L3; Figs 9–11: larvae of *G. colchidaria*: 9, L3; 10, L2; 11, L4.

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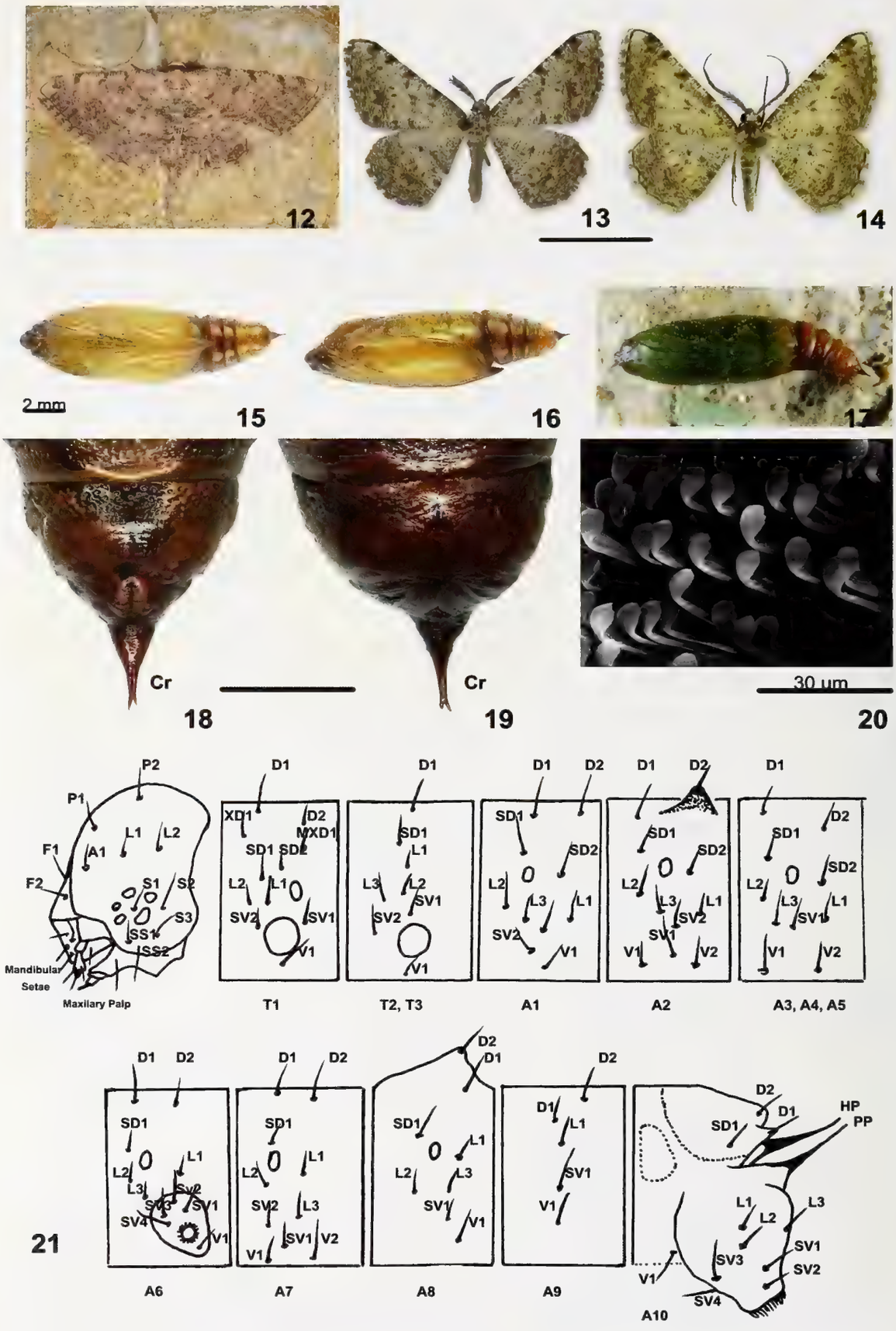

Plate 2. Figs 12–14: Adults of *Gnopharmia*: 12, *G. colchidaria* (female, freshly emerged; culture F); 13, *G. kasrunensis* (holotype, male); 14, *G. colchidaria* (male) (scale 1 cm); Figs 15–16: Pupa of *G. colchidaria*: 15, ventral view, 16, lateral view (scale 2mm); Fig. 17: Pupa of *G. kasrunensis*, ventral view (one day after pupation); Fig. 18: Pupa of *G. kasrunensis, posterior part* (male, ventral view; Cr: cremaster); Fig. 19: id., pupa of *G. colchidaria*, female (scale 1mm); Fig. 20: floricomous setae (distal part) on female ovipositor (scale on figure); Fig. 21: Setal map of *G. colchidaria* and *G. kasrunensis* larvae.

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but the basal process of the sacculus is distinctly longer in *G. colchidaria*. In *G. kasrunensis* both of these projections seems to be equal in length (Figs 30, 31).

For SEM photography male genitalia have been dehydrated in 70%–96% and 100% ethanol. For drying with HMDS (1, 1, 1, 3, 3, 3-Hexamethyldisilazan) the HMDS-protocol (Oshel 1997) was used. According to this protocol the genitalia have been transferred from 100% ethanol to a 1:1 ethanol-HMDS mixture and then to 100% HMDS. The specimens were dried by evaporation of HMDS.

SEM photos were made using a Hitachi S-2460N SEM at Zoologisches Forschungsmuseum Alexander Koenig.

RESULTS

Rearing report and field observations

The female of culture-A (*G. kasrunensis*) laid eggs in a plastic box containing leaves of *Prunus lycioides*. Most larvae hatched from these eggs, but died because of lack of fresh food plants. Leaves of *P. lycioides* carried with us had dried out and no *P. lycioides* or another possible host plant was available. Females of cultures B–F (*G. kasrunensis*) laid eggs (*Prunus scoparia* was added to the containers) just two to three days after collecting and two days later, L1-larvae started to feed successfully.

Despite attempting to provide relatively stable conditions to the larvae, many of them died in different stages. Of 79 L1-larvae of *G. kasrunensis* in cultures B, C and D, just 42 survived to L2, and only 18 of them moulted again (after 7–8 days). L3-larvae were feeding almost continuously, but they were more active in the morning and in the afternoon. Larvae continued to perish during this stage as well. 6–8 days later just 7 larvae moulted to L4. They fed again for 5–6 days, but during this time all but one died. Fully grown (25.6.2009) the last remaining larva of this species (culture C) stopped feeding and rested under pieces of tissue paper in its container, then pupated (see Fig. 17), without spinning or producing a cocoon.

L1 stage of *G. colchidaria* took 7–9 days. Many of the larvae again died later during several instars. Of 38 L1-larvae (cultures E and F) just 24 moulted to L2. 5 larvae died in this instar. L3-stage took 7–8 days and of 19 larvae just three reached L4. The feeding period of the last instar is longer than that of the last species (9 days). Fully grown, just one larva pupated (Figs 15, 16).

At a temperature of 25–28° C, a male of *G. kasrunensis* emerged after 18 days (July 12, 2009; dissected). At a same temperature, one female of *G. colchidaria* emerged from pupa after 16 days (July 18, 2009; Fig. 12).

All seven females of the cultures G–M (collected from Lorestan, Hamadan and Kordestan provinces) laid eggs (a total of 187 eggs) which were brought to Germany, in order to find and to test suitable food-plants there. 163 L1-larvae hatched but none of the plants offered was accepted and all larvae died.

Host-plants

Prunus scoparia has been offered to the L1-larvae of *G. kasrunensis* and *G. colchidaria* (cultures B–F) and was readily accepted by all of them. This plant may be considered as the main food resource for both, *G. kasrunensis* and *G. colchidaria,* also under natural conditions.

To the L4-larva of *G. colchidaria* (cultures E and F), feeding on *P. scoparia* before, I offered two other Prunus species (*Prunus haussknechtii* C. K. Schneid. and *Prunus lycioides* (det. H. Akhani and M. Yazbek), but no feeding marks were found in either of them.

To L1-larvae of *G. kasrunensis* from Tole-Heidari (culture A) the common almond (*Prunus dulcis* (Mill.) D.A.Webb) and later *Prunus haussknechtii* C. K. Schneid. have been offered, but none of them was accepted. *Prunus scoparia* was not available at that time.

All larvae of the cultures G–M have been brought to Germany. It took 2 days to find a plant of *Prunus dulcis* (Miller) D.A. Webb. During this period I offered *Crataegus monogyna* Jacq., but it was not accepted by the larvae and more than half of them died. The others died in the next days because they also did not accept *Prunus dulcis*.

Morphology of preimaginal stages

Ovum

Ovum: Elliptical, surface rough, green in colour (just after deposition), turning red-ochre after one or two days (Fig. 5). Most of them were deposited separately in a vertical, upright position, but some were laid in clusters as shown in Fig. 5.

Under warm conditions, L1-larvae developed very quickly and emerged just after 4–5 days (table 1).

There is no significant difference in the shape or the structure between the eggs of these two species.

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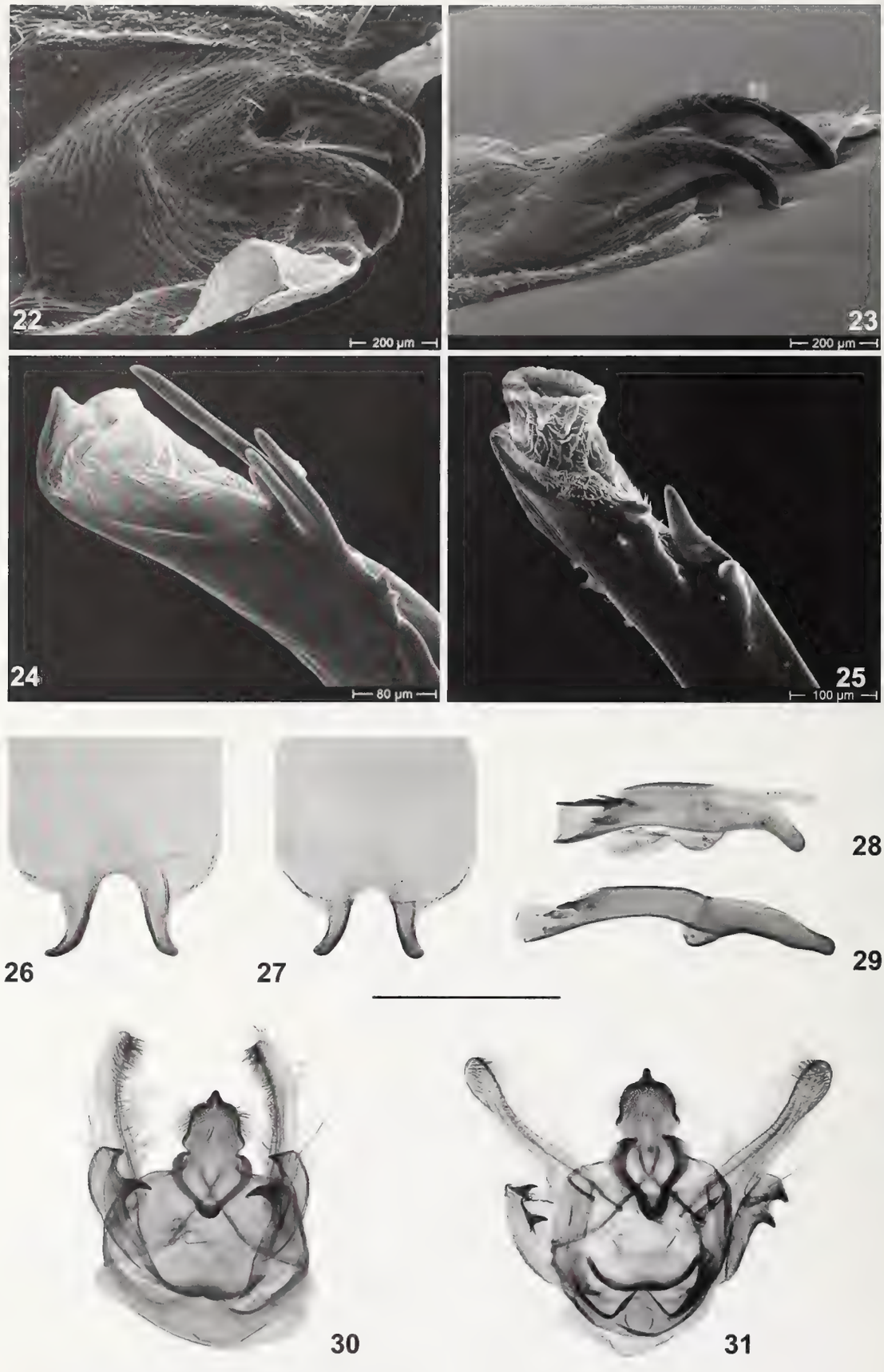

Plate 3. Figs 22–23: SEM photos of sternite A8, with 'octavals': 22, *G. kasrunensis*; 23, *G. colchidaria*; Figs 24–25: SEM photos of apical part of aedeagus: 24, *G. kasrunensis*; 25, *G. colchidaria* (scale on figures); Figs 26–27: Sternite A8: 26, *G. kasrunensis* (holotype, male); 27, *G. colchidaria* (male); Figs 28–31: male genitalia: 28, *G. kasrunensis* (aedeagus); 29, *G. colchidaria* (aedeagus); 30, *G. colchidaria* (genital capsule); 31, *G. kasrunensis* (genital capsule). Scale 1 mm.

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Larval stage

***G. kasrunensis* Wehrli, 1939**

L1: 1.4–2.1 mm (5 days after haching) in length, with two longitudinal pale-brown bands on green background, starting from the posterior end of the medio-dorsal area and continuing to the head. Head and end of the body are brown. A longitudinal brown band, similar to the dorsal band, runs ventrally from posterior end to the head. The thoracic legs and abdominal prolegs are dark brown.

L2: (Fig. 6)**:** length 6.2–7.00 mm (11 days after hatching), brown medio-dorsal bands change (in compare to L1) from brown to more green, similar to the ground colour, but at the end of L2 the rest of brown bands are distinctly visible on two-thirds posterior of body. The brown ventral band vanishes toward head. In this stage, there are two dorsal processes at the base of the D2 seta dorsally on segment A2 (see Fig. 21). The tips of these processes are dark brown or black.

L3 (Fig. 8)**:** 9.6–10.5 mm (20 days after hatching), exhibits nearly the same colour patterns as found in the fully grown larvae. The dorsal area is completely green with medio-dorsal brown bands (from A10 to A6). Ventrally, the green colour is extended, but on A6–10 there are still soft brown colour band. During L3, the colour of the dorsal processes at the base of the D2 seta (of the A2 segment) changes from dark brown or black to brown.

L4 (Fig. 7): 19.2–25.8 mm (28 days after hatching), completely green in colour, with a longitudinal medio-dorsal brown bands running from the A10 to the A6 segment. The dorsal processes of the A2 segment are brown, but in two cases, changed to green.

***G. colchidaria* Lederer, 1870**

L1: 1.2–2.2 mm (7 days after hatching), coloration very similar to *G. kasrunensis*, but here longitudinal dorso-medial bands start from the posterior end and continue along two-thirds of the body dorsally (from A10 to A4–5).

L2: (Fig. 9)**:** 6.5–7.1 mm (12 days after hatching), brown dorso-medial bands continue to the head, the ventral band extends slightly to the lateral. The two dorsal processes of A2 are clearly dark brown to black in colour (like in *G. kasrunensis*).

L3: (Fig. 10) 9.7–10.7 mm (20 days after hatching), completely different in comparison with *G. kasrunensis***:** dorsal and ventral longitudinal brown bands extend laterally and the green colour is reduced to the lateral area. Black dorsal processes on the A2 segment are clearly visible.

L4: (Fig. 11): 19.2–26.1 mm (26 days after hatching), predominantly brown, with some yellow-green colour laterally and dorsally. The A2 dorsal processes are brown, like the surrounding area.

The position of the primary setae of the L4- larvae of both species does not exhibit any differences. (see setal map, Fig. 21). For nomination of seta used McGuffin (1977) and Stehr (2005).

Pupa

Pupae of both species are obviously very similar in size and colour. (Figs 15–19). They are slender, about 12.8–13 mm in length, the head section rather acute, almost triangular; the elongated cremaster (length 0.6 mm) bears two terminal spines of different length (right spine broken in fig. 19). Until the second day after pupation the colour remains green, and then changes to brown. The pupal exuvia is mid-brown, too. More material is needed in order to compare the pupal characters of both species thoroughly.

Distribution (Fig. 32). According to our present knowledge, *G. kasrunensis* and *G. colchidaria* occur sympatrically in most parts of the Zagros Mountains. *G. kasrunensis* has been described from Kazeroun (Fars prov., Iran) and is distributed in the central and eastern Zagros with some small populations in western Zagros and central Alborz. Only two specimens of this species were collected at Sayhakil in Musandam (Oman). *G. colchidaria* occurs in nearly all parts of Zagros, furthermore there are populations in south-eastern Iran, and in the Alborz (vic. Tehran, Qazvin, Zanjan, and Gilan). The species has been described from Helenendorf (East Azerbaijan, Transcaucasia; present name: Xanlar), and there are additional reports from Armenia (ssp. melanotaenia Wehrli, 1938) and other regions of S. Caucasus. The map is based on material present in the collections studied. Probably these two species have a wider distribution, but the author so far had no access to further material proving this.

Bionomic data. According to the analyzed label data, derived from several collections, *G. kasrunensis* has been collected between the second week of February and the second week of September. The flight period of *G. colchidaria* dates from early March to late October. *G. kasrunensis* flies at altitudes from 200 up to 2200 m, *G. colchidaria* from sea level to 2800 m. Both species probably are (at least) bivoltine in most places, but may be univoltine in the North of Iran and at higher elevations. Overwintering stage obviously is the pupa.

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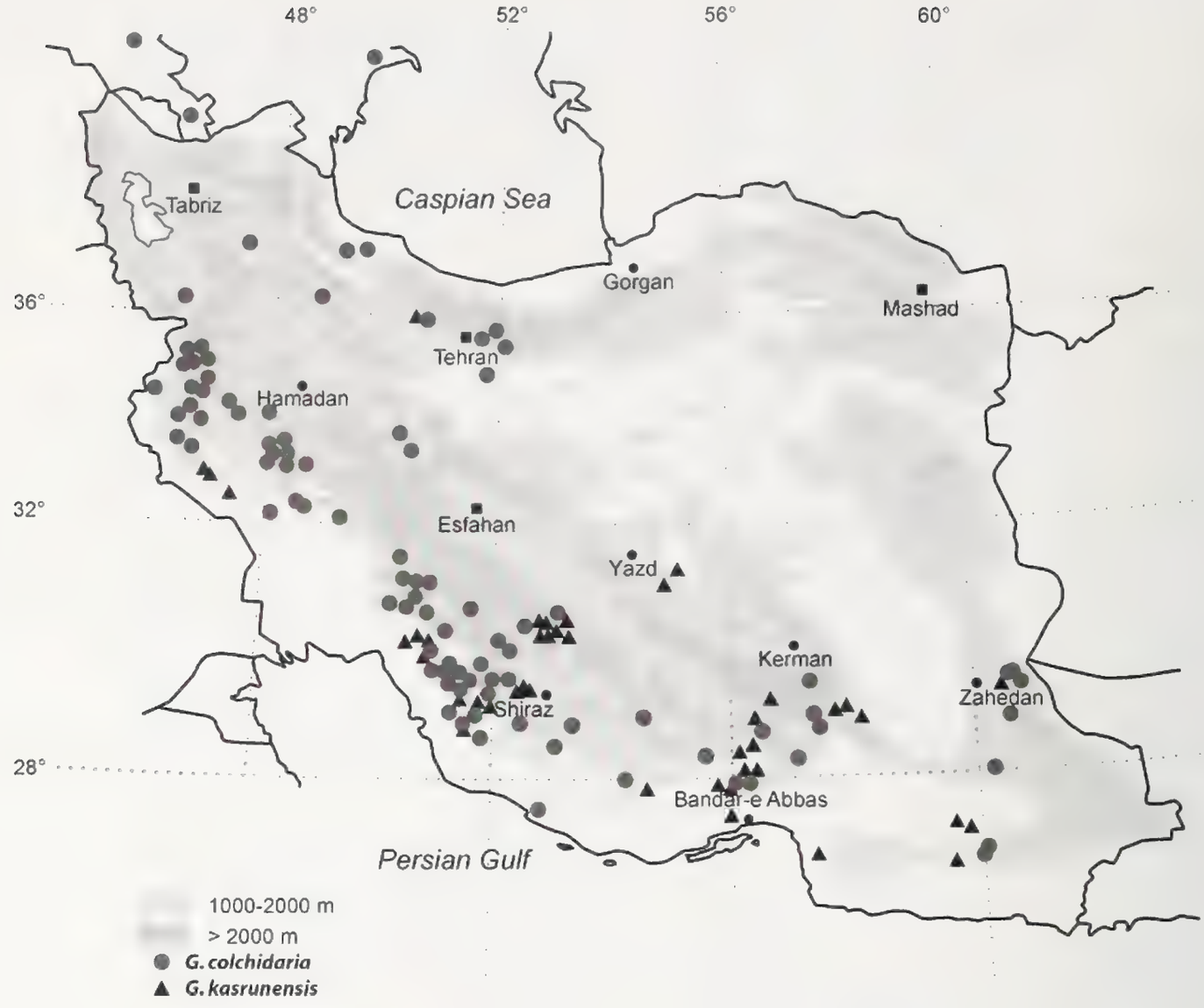

Fig 32. Distribution map of *G. kasrunensis* and *G. colchidaria* in Iran.

DISCUSSION

Despite intensive search on many *Prunus* shrubs in a number of Iranian localities for immature stages of *Gnopharmia,* no eggs, larvae or pupae were found in the nature. Of course, it is often difficult to find eggs of moths in the field, but in case of *Gnopharmia* these difficulties may also be related to the existence of a so-called "floricomus" on the ovipositor of *Gnopharmia* females. Numerous specialized ("scoop-shaped") setae (Fig. 20) on the papillae anales probably enable the females to scratch particles from the surface of the bark to cover and camouflage the eggs. This behaviour has been observed in the W. European Ennomine species *Theria primaria* Haworth, 1809 (Stokoe 1948: 186, pl. 39:1), females of which have a very similar ovipositor with almost identical, specialized setae. This hypothesis is supported by the fact that the papillae anales of almost all females studied are spoiled with dust or bark-particles retained near the setal bases (Scoble & Krüger, 2002, D. Stüning, Bonn, pers. comm., unpublished).

Prunus scoparia as the most probable natural host plant of *G. kasrunensis* and *G. colchidaria* is well distributed in many parts of the Zagros Mountains. During the last years this plant has also been intensively grown by local people and became more widely distributed, as 'bitter almonds' became more frequently used by the pharmacological industry in Iran. *G. kasrunensis* and *G. colchidaria* fly sympatrically at many localities in Iran (Fig. 32). Lar-

vae of both species are very similar morphologically and the young larvae (L1, L2) are also without clear differences in colour and pattern. However, grown larvae (L3, L4) can be separated.

The reason for the high mortality of the larvae during all stages is not clear to us. Alteration of climate in the vehicle, low quality of the food plant, obstruction by sunlight or artificially damp environment (wet paper towels were provided to keep the food fresh) could have been the reason for bacterial or viral infection which killed the larvae.

Further studies on the biology of this interesting moth genus will be carried out during the 2010 collecting season.

Acknowledgments. I deeply thank Axel Hofmann (Breisach) and Dr. Jörg-Uwe Meineke (Kippenheim) for their helpful advice during our common field work, and express my sincere thanks to Prof. Dr. Hossein Akhani (Tehran) and Mariana Yazbek (Lebanon) for the determination of host plants. Furthermore, I do not forget valuable comments by Dr. Robert Trusch and Günter Ebert (Karlsruhe), Dr. Dieter Stüning (Bonn) and Dr. Axel Hausmann (Munich). I thank Lily Wescott and Tom Swinehart (Bonn) for proofreading of the first draft, Stefan Scharf (Karlsruhe) for preparing the digital map of Middle-East, Ulla Kreutz (Meckenheim) for processing of the digital images, Bernd Müller (Berlin), Michael Falkenberg (Karlsruhe) and Maryam Boroomandi (Bonn) for their friendly help during different steps of this project. Special thanks go to Dr. Montazami, Alireza Naderi, Mohammad-Ebrahim Sehhati and other colleagues of Iran Department of Environment for their collaboration during our 2009 excursion and also colleagues of Hayk Mirzayans Insect Museum in the Iranian Research Institute of Plant Protection (HMIM, Tehran) for their friendly collaboration in the project *Gnopharmia*. I am grateful to Hamid Valipoor (Ghoochan) and Mahdi Nasiri (Dorud) for their aid in the field trip of 2009 in Iran, to Professor Dr. J. W. Wägele (ZFMK, Bonn) for his promotion and DAAD (Deutscher Akademischer Austausch Dienst) for the financial support of this project.

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Two new species of the *Plutodes costatus*-group from the Philippines and Indonesia (Lepidoptera, Geometridae, Ennominae)

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Abstract. Two new species, *Plutodes magdelinae* sp. n. from Mindanao Island, the Philippines, and *P. thorbeni* sp. n. from Sulawesi, Indonesia, are described. Pattern and coloration clearly indicate that they are members of the *P. costatus*-group. Besides the well-known, wide-spread and often abundant *P. costatus* Butler, 1886, other members of this species-group are *P. warreni* Prout, 1923, and *P. moultoni* Prout, 1923. The latter species, described from Peninsular Malaysia, is redescribed. It is very similar externally to *P. magdelinae* sp. n., but clearly different in the genitalia morphology. Its known range of distribution is fairly extended, based on new records. *P. hermanowskii* Stüning, 2005 (Luzon, Philippines) is the most recently described species in this group. DNA barcoding of all involved taxa revealed that they are well differentiated also on the genetic level.

Key words. *Plutodes*, new species, *P. magdelinae* sp. n., *P. thorbeni* sp. n., Philippines, Indonesia, DNA barcoding.

INTRODUCTION

Species of the genus *Plutodes* Guenée [1858] are characterized by broadly unipectinate antennae in both, males and females, and their striking wing-pattern of yellow ground colour with bands and patches in reddish-brown or grey, the latter often highlighted by margins of iridescent scales. Parsons et al. (1999) listed 27 species as a whole, distributed from the NW Himalayas (Sabathu, type-locality of *P. warreni*) and Nepal (Yazaki, 1992, 1993, 1994: eight species) to tropical Australia (*P. signifera* Warren, 1896; cf. McQuillan & Edwards, 1996). Holloway [1994] redescribed the genus and recorded seven species from Borneo. He also provided a definition for the tribe Plutodini.

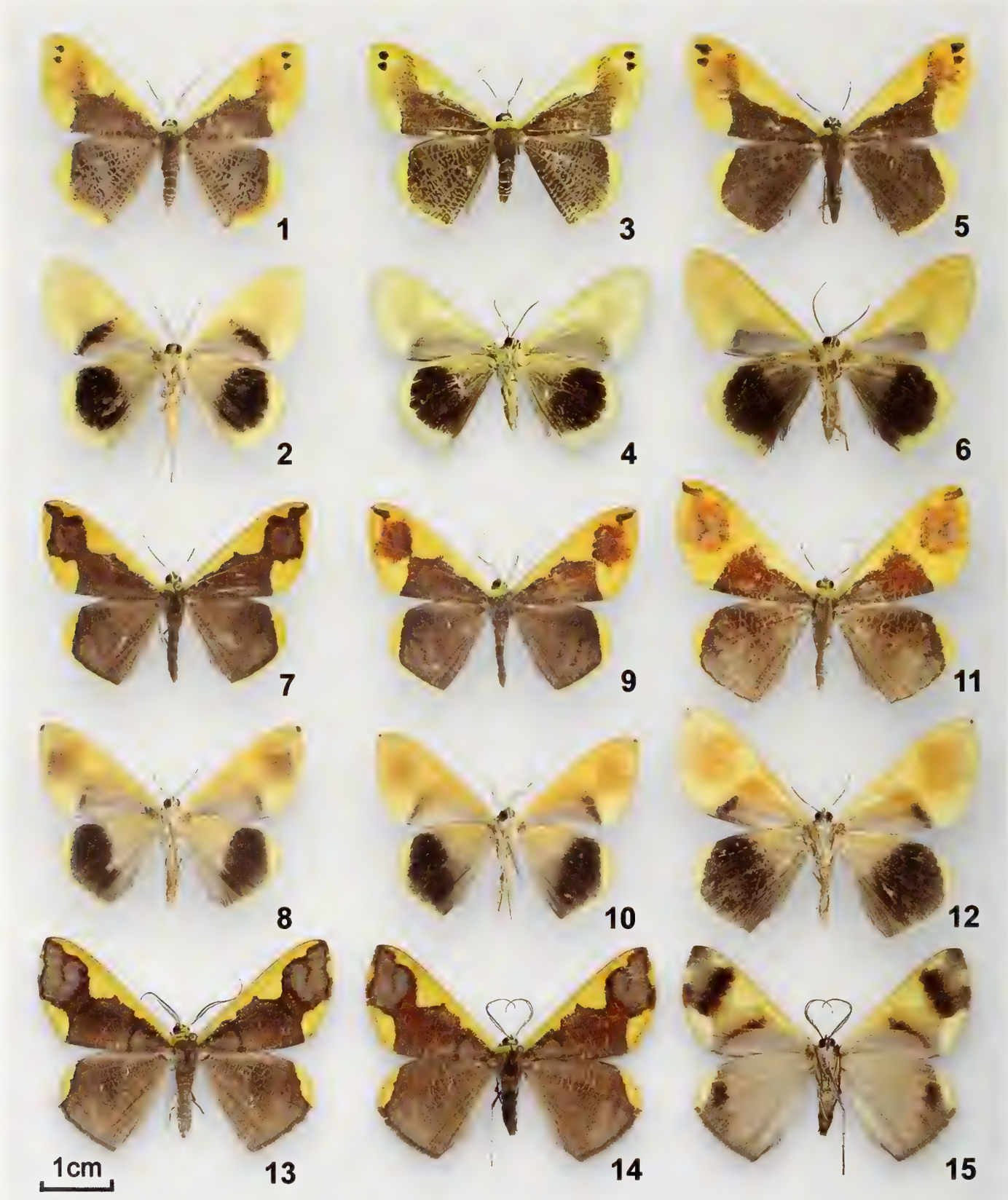
Species of the *P. costatus*-group are distinguished from the typical species of *Plutodes* (like the type-species *P. cyclaria* Guenée and its relatives) externally by larger size and by the hind wings coloured brown with only some remnants of the yellow ground colour. Also in the forewings the range of brown colour is enlarged, most definitely so in *P. costatus* and *P. warreni*. *P. moultoni* has the yellow areas of the forewings more extended, but has the apical patch, which is very conspicuous in the two species mentioned before, reduced to minor orange-coloured remnants. Instead, the apical region is marked by a pair of black, outwardly pointed spots. *P. hermanowskii* is transitional to the core-group in having oval apical patches to the forewings, similar to the majority of species related to *P. cyclaria*.

The two new species described herein clearly belong to the *P. costatus*-group, the one from Mindanao being strikingly similar externally to *P. moultoni*, but clearly different in male genitalia. *P. thorbeni* from Sulawesi is also distinctive in its habitual features, but closer to *P. costatus* externally.

DNA barcodes were obtained at the Canadian Centre for DNA Barcoding, University of Guelph, Canada, in the course of a project called 'All Leps' (cf. http:// www.lepbarcoding.org).

MATERIAL AND METHODS

This study is based mainly on material of the Lepidoptera collection of the Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany (ZFMK). In addition, the collections of the Zoologische Staatssammlung, Munich (ZSM), including the collection Claude Herbulot, and two important private collections (coll. M. D. Sommerer, Munich, and coll. M. Schaarschmidt, Leipzig) were studied. The relevant material housed at The Natural History Museum, London (NHM), has been checked by J. D. Holloway, and images of the holotype of *P. moultoni* Prout and its labels were provided by the collection manager at the NHM Lepidoptera department.



Figs 1–15. Adults of *Plutodes* spp. 1–4. *Plutodes moultoni* Prout, 1: ♂, N. Thailand, 2: underside; 3: ♂, Sumatra, 4: underside of 3; 5–6. *Plutodes magdelinae* sp. nov., holotype ♂, Mindanao; 5: upper side, 6: underside; 7–12. *Plutodes thorbeni* sp. nov., Sulawesi, 7–8: holotype ♂, 9–12: ♂ paratypes (8, 10, 12: underside); 13–15. *Plutodes costatus* Butler; 13: ♂, Sumatra; 14: ♀, Sumatra; 15: underside of ♀.

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External features and genitalia of all species were examined. The illustrations of whole moths (upper side and underside) and moth genitalia were prepared from digital images, and were subsequently edited in Adobe Photoshop. The terminology of the genitalia largely follows that of Klots (1956).

A total of 38 specimens of the "*Plutodes costatus* species-group" has been processed at the Canadian Centre for DNA Barcoding (CCDB) in order to obtain DNA barcode sequences (COI, 5', barcode fragment, 658 bp.), most of them successfully, though partly 15 years old (for details of the procedure see Ivanova et al., 2006).

Abbreviations. NHM: The Natural History Museum, London; ZFMK: Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany; ZSM: Zoologische Staatssammlung, Munich, Germany.

TAXONOMY

Redescription of *Plutodes moultoni* Prout (Figs 1–4, 16–18, 19, 20)

Plutodes moultoni Prout, 1923, Annals and Magazine of Natural History (9) 11: 321.

Type locality. [Peninsular Malaysia] Selangor, Bukit Kutu, 3457 ft.

Holotype ♂. NHM, London.

Male (Figs 1–4). Wingspan 31–38mm, length of forewing 17–20mm. Apex rounded, termen evenly curved, tornus rounded. Fovea lacking. Vein R_1 of forewing arising from cell close to the common stem of R_{2-5}, anastomosing with Sc at varying length. R_2 branching off from the middle of the common stem of R_{3+4}. Forewings yellow, with a greyish-brown basal area and a distal, indistinct, orange patch, both parts broadly connected. The connecting band is always present, the orange patch may be more or less distinctly developed. Distal to and rarely connected with the orange patch are two blackish-brown, subapical, irregularly triangular spots, their tips pointing towards the termen. Basal area with an ill-defined anterior margin, reaching well into the discal cell, an acute protuberance at the position of the discal vein and a short concavity prior to the connection with the apical patch. Posterior half with indistinct, transverse, greyish striation. Iridescent scales are found along basal two-thirds of costa, anterior margin of basal greyish-brown area, around orange patch and densely covering the triangular spots. Fringe of termen yellow, that of hind-margin brown.

Hind wings with margin evenly rounded, fringe yellow. A narrow yellow marginal band from apex to tornus, slightly broader at apical half. Remaining part of hind wing dark blackish or greyish brown, with extensive transverse striation. Distal margin of dark area lined with iridescent scales. Discal spot or streak not visible. In some specimens a postmedial, double, indistinct zigzag-line present.

Underside of both wings lighter yellow, forewings with a transverse, slightly curved, blackish bar from tornus towards middle of costa, but not reaching the latter, less strongly developed or absent in Malaysian (including the type) and Sumatran specimens (see Figs 2, 4). A band proximal to this bar rather greyish-brown than yellow. Hind wings on underside with a large, blackish, oval patch, touching or almost reaching the anterior margin near apex. Basal area of wings light yellow or suffused with darker scales (the latter character found again in specimens from Malaysia and Sumatra). Distally a broad, light yellow marginal band of even width. Fringe yellow.

Head with frons distinctly narrower than eye-diameter, smoothly scaled, greyish-brown, but with groups of upright, narrow scales at dorsal margin. Vertex with larger, yellow scales and white scales between the antennal bases, basal segments and dorsal side of lower part of antennae also white. Palps slightly up-curved, of a light greyish-brown colour, the third segment small, tapering. Proboscis well developed. Antennae unipectinate, with longest branches about 7,5 times as long as the diameter of the flagellum shaft. Terminal one third of antennae simple. Patagia and anterior parts of tegulae yellow, posterior part of tegulae, thorax and abdomen greyish brown. Tibiae of hindlegs not dilated, thus without hair-pencil. Setal comb on third abdominal sternite as well as sterno-tympanal spine lacking. Tympanal organ without lacinia.

Male genitalia (Figs 19, 20). Valves elongate, weakly sclerotized, apex rounded, lamina internally densely setose. Valve costa, like the whole genitalia capsule, weakly sclerotized, the sacculus being the only strongly sclerotized part. It reaches a little more than half the length of the ventral valve margin, bearing an acute distal tooth-like process with a second tip at some distance pointing basally. A strong basal process with a more rounded tip is directed dorsally. There is also a roundly protruding area opposite to the sacculus on the external surface of the valve. Uncus broad, dorso-ventrally flattened, dorsally setose, with a dense group of stiff, narrow, upright scales near base, slightly curved ventrad, with pointed tip. Socii present, small, but with long setae. Gnathos with narrow lateral arms, central part a broad plate at right angles towards the lateral arms, without medial process. Transtil-

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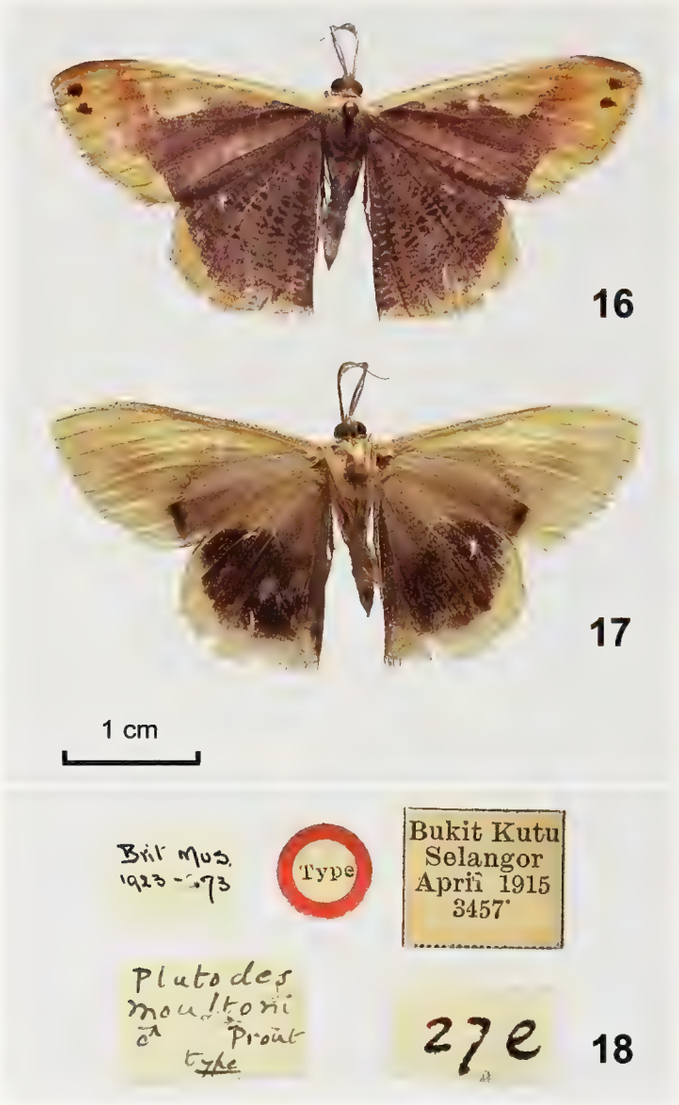

Figs 16–18. Holotype ♂ of *Plutodes moultoni* Prout, 1923. 16: upper side; 17: underside, 18: labels. Images reproduced by kind permission of the Trustees of the Natural History Museum, London.

la a triangular, curved, cap-like plate, its tip pointing distally, with a pair of short, narrow processes arising from the proximal corners and directed caudally. Juxta a round plate, with a v-shaped incision with irregular margins dorsally. Saccus narrow, strongly elongate, rounded distally. The aedeagus straight, club-shaped, with a stout proximal and a narrow distal half, the vesica with an elongate, semi-cylindrical sclerotization and a small group of cornuti, a long, curved, distal one and 3–4 distinctly smaller ones, arising from a common base. Bulbus ejaculatorius moderately large, about half the length of the aedeagus.

Male genitalia of specimens from N Thailand a little smaller and slightly differing to those from Sumatra in the length-proportions of the saccular processes (Fig. 20).

Female similar to male, wingspan 35–37 mm, length of forewing 19–21 mm, with forewings a little broader and termen more strongly curved. Pectinations of antennae about one fifth shorter than in males and a little narrower.

Material studied. Type material. Holotype, ♂, [Peninsular Malaysia], Bukit Kutu, Selangor, April 1915, 3457'; coll. NHM (see Figs 16–18). J. D. Holloway (London, pers. comm.) mentioned two more specimens from Peninsular Malaysia in coll. NHM, but Prout (1923) obviously only had one specimen at hand when he described this species (i.e. the holotype).

Further material. 1♀, [Peninsular] Malaysia, Taiping [~ 4°51'N 100°46'E], May [19]79;

4♂, N. Sumatra, vic. Tiga-Dolock, 18., 25.v.1972, leg. Roesler & Küppers; coll. ZFMK; 1♂, N. Sumatra, Dolok Merangir, 21.ix.–5.x.1967, leg. Dr. E. Diehl, ex coll. Dr. R. Bender, coll. ZSM. (more specimens from N. Sumatra in coll. M. D. Sommerer, Munich).

2♂, Borneo, Sabah, route Keningau-Kimanis PK 28.5, 1300m, 8., 11.viii.1991, leg. Haxaire. Herbulot collection in coll. ZSM;

1♂, S. Vietnam, Prov. Quang Tri, Partung, Da Krong, 1.–3.vi.2005; coll. ZFMK;

1♂, SE Thailand, Prov. Trat, Kho Chang, 0m, 25.–30.xi.2004, leg. T. Ihle; coll. ZFMK;

8♂, N. Thailand, Chiang Mai Prov., Doi Suthep, 1050m, 25.xi.2000, leg. D. Stüning; 4♂, same locality, 1100m, 15.–19.i.2008, leg. T. Ihle; 1♂, N. Thailand, Chiang Mai Prov., Doi Angkhang, W Fang, 1600m, 21.v.2004; 1♀, N. Thailand, Chiang Mai Prov., Doi Inthanon, 1500m, 28.–30.iv.2006, leg. T. Ihle; 1♀, N. Thailand, Mae Hong Son Prov., ca. 30km E Khun Yuam, 950m, 1.v.2006, leg. T. Ihle; coll. ZFMK;

16 specimens from Doi Suthep, Chiang Mai Prov., are kept in the collection of Bro. Amnuay Pinratana, St. Gabriel's College, Bangkok.

1♂, S. China, S. Yunnan Prov., Mangxi Ba Mts., Simao distr., 18km S Simao city, 1280m, 16.iii.–10.iv.2000, ex coll. Dr. R. Brechlin. Coll. ZFMK.

Distribution and bionomics. Peninsular Malaysia (type-locality), Borneo, Sumatra; Vietnam, SE & N. Thailand, S. China (first record for all localities except Peninsular Malaysia). Specimens have been collected in January, March-April, May, June, Sept.–October, November; at el-

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evations between 0 and 1600m. The immature stages are unknown.

***Plutodes magdelinae* sp. nov.** (Figs 5, 6, 21)

Male (Figs 5–6). Wingspan 37–38mm, length of forewing 21–22mm. Apex rounded, termen evenly curved, tornus rounded. Fovea lacking. Vein R_1 of forewing arising from anterior vein of cell close to the common stem of R_{2-5} – both at rather large distance from upper corner of cell – , anastomosing with Sc at varying length. R_2 branching off from the middle of the common stem of R_{3+4}. Forewings yellow, with a greyish-brown basal area and a distal, indistinct, orange patch, both parts narrowly connected. The connecting band is always present, the orange patch may be more or less distinctly developed. Distal to the orange patch are two blackish-brown, subapical, elongate triangular spots, their tips pointing towards the termen. Basal area with an ill-defined anterior margin, reaching just a little beyond the posterior margin of the discal cell. Posterior half with indistinct, transverse, greyish striation. Iridescent scales are not very obvious, weakly covering basal two-thirds of costa, anterior margin of basal greyish-brown area, orange patch and the submarginal area near the triangular spots. Fringe of termen yellow, that of hind-margin brown.

Hind wings with margin evenly rounded, fringe yellow. A narrow yellow marginal band from apex to tornus, distinctly broader at apical half. Remaining part of hind wing dark blackish or greyish brown, with extensive transverse striation. Distal margin of dark area lined with iridescent scales. Discal spot visible as a short, curved, white streak. Postmedial ziczac-line absent.

Underside of both wings (Fig. 6) lighter yellow, forewings with a broad, posterior, greyish-brown band between hind margin and posterior vein of cell, but not reaching termen. Hind wings on underside with a large, blackish-brown, oval patch, almost reaching the anterior margin near apex. Basal area of wings strongly suffused with darker scales. Distally a rather broad, light yellow marginal band of even width. Fringe yellow.

Head with frons distinctly narrower than eye-diameter, smoothly scaled, greyish-brown, with thin white lateral margins, but with groups of upright, narrow scales at dorsal margin. Vertex with larger, yellow scales and white scales between the antennal bases, basal segments and dorsal side of lower part of antennae also white. Palps slightly up-curved, basal segment predominantly white, second and third of a light greyish-brown colour, the third segment small, tapering, with a white tip. Proboscis well developed. Antennae unipectinate, with longest branches about 8,5 times as long as the diameter of the flagellum shaft. Terminal one third of antennae simple. Patagia and anterior parts of tegulae yellow, posterior part of tegulae, thorax and abdomen greyish brown. Tibiae of hindlegs not dilated, thus without hair-pencil. Setal comb on third abdominal sternite as well as sterno-tympanal spine lacking. Tympanal organ without lacinia.

Male genitalia (Fig. 21). Valves elongate, weakly sclerotized, apex rounded, lamina internally densely setose. Valve costa, like the whole genitalia capsule, weakly sclerotized, but sacculus with a prominent and strongly sclerotized, plate-like process, inserting in an upright position close to the ventral margin of the saccular region. It is getting broader distally, with an acute tip, narrower basally, with a rounded, very short, dorsal bulb. Outer margin of the plate densely covered with short, appressed setae. Length a little more than half the length of the ventral valve margin. Uncus broad, dorso-ventrally flattened, dorsally setose, with a dense group of stiff, narrow, upright scales near base, slightly curved ventrad, with pointed tip. Socii very small, marked by a few long setae only. Gnathos with narrow lateral arms, central part a broad plate at right angles towards the lateral arms, without medial process. Transtilla a triangular, curved, cap-like plate, its tip pointing distally, with a pair of short, narrow processes arising from the proximal corners and directed caudally. Juxta a narrow plate, with a deep, v-shaped incision dorsally. Saccus narrow, strongly elongate, rounded distally.

The aedeagus almost straight, club-shaped, with a stout proximal and a narrow distal half, the vesica with an elongate, semi-cylindrical sclerotization and a small group of 5–6 cornuti, not much differing in size. Bulbus ejaculatorius moderately large, about half the length of the aedeagus.

Diagnosis. *P. magdelinae* is distinguished from the externally very similar *P. moultoni* by slightly larger size, the wing-shape (forewings more elongate with more strongly oblique termen), a narrower greyish-brown basal area (anterior margin just reaching the posterior vein of discal cell, distal margin more strongly concave). The subapical, black, triangular spots are larger and more distinctly acute towards the termen. In the hind wings, the yellow marginal band is much narrower at tornal half. On underside, the oblique bar on forewing from tornus to costa is absent, the basal area of hind wing is much darker.

In the male genitalia, the elongate, simple plate on sacculus without a separate basal process is distinctive.

Female unknown.

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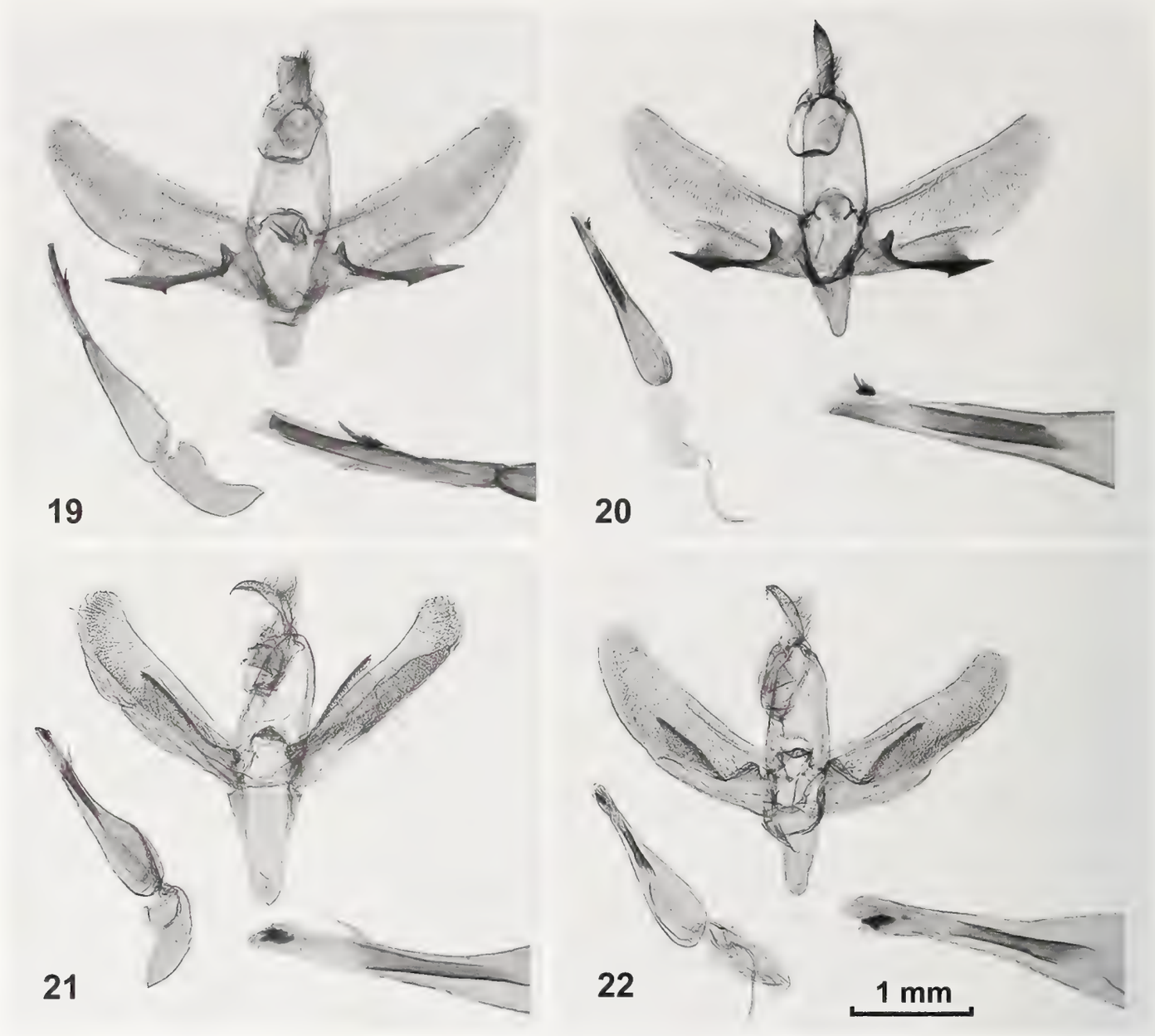

Figs 19–22. ♂-genitalia of *Plutodes* spp. 19: *P. moultoni* Prout, Sumatra (vesica partly everted); 20: *P. moultoni* Prout, N. Thailand; 21: *P. magdelinae* sp. nov., paratype, coll. no. LEP 2010/ 469-2; 22: *P. thorbeni* sp. nov., paratype, coll. no. LEP 2010/ 472-3. (bottom left: aedeagus, bottom right: enlarged apical part of aedeagus).

Type-material. Holotype, ♂, "Philippinen, Mindanao (Prov. Davao del Sur), Mt. Apo, SE-route via Kapatagan, 1570m, 10.–12.July 1996, prim. forest, leg./ ex coll. Dr. Ronald Brechlin. Coll. ZFMK, coll. no. LEP 2010/468 (Biodat).

Paratypes. 2♂, same data as holotype, coll. nos. LEP 2010/469-1, 469-2; 1♂, Philippinen, Mindanao, Mt. Kitanglad, Intavas, 600m, 8° 10'N 124°56'E, 23.–24. ii. 2009, leg. J. H. Lourens & K. Knoblich, coll. ZFMK, coll. no. Lep 2010/470;

1♂, Philippinen, Mindanao, Mt. Dalongdong, 9.–17. viii.1999. Coll. M. Schaarschmidt, Leipzig. ["Dalongdong" correctly is named Dolongdong and is a village on a high plateau at the western slopes of Mt. Kalatungan, 45km SW Talakag, 40km W Maramag, 07°53'N 124°40'E; J.H. Lourens, Luzon, in litt.]

Distribution and bionomics. Probably endemic to Mindanao Island, the Philippines, only known from Mt. Apo, Mt. Kitanglad and the Dolongdong high plateau near Mt. Kalatungan. Specimens have been collected in February, July and August at 600m and 1570m a.s.l. The immature stages are unknown.

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Etymology. The present new species is dedicated to Magdeline Camille Vlasimsky (formerly Frankfurt a. M., Germany, now Dallas/ Texas), in recognition of her and her parents' Lezlie and Stan valuable contribution to the taxonomic research of the author and to conservation of biodiversity.

***Plutodes thorbeni* sp. n.** (Figs 7–12, 22)

Male (Figs 7–12). Wingspan 34–39mm, length of forewing 19–23mm. Apex slightly acute, termen evenly curved, tornus rounded. Fovea lacking. Vein R_1 of forewing arising from anterior vein of cell close to the common stem of R_{2-5} – both at rather large distance from upper corner of cell- , anastomosing with Sc at varying length. R_2 branching off from the middle of the common stem of R_{3+4}. Forewings yellow, with a greyish-brown basal area and a distal, more or less distinct, irregularly quadrangular, dark brown to orange-brown, rarely light orange patch, both parts broadly or narrowly, sometimes not connected. Internal surface of the patch with a dark, waved line. Apical corner of the patch forming an elongate, black spot, its tip connected with the apex of the forewings. The spot is most distinctive in specimens with a reduced, orange, apical patch. Basal area with an ill-defined anterior margin, reaching well beyond the posterior margin of the discal cell, with an acutely triangular protuberance at the position of the discal vein and a broad concavity prior to the connection with the apical patch. Posterior half with indistinct, transverse, greyish striation. A margin of iridescent, leaden-grey scales along the anterior margin and around the apical patch, including the black apical streak, but not along distal margin. Fringe of termen yellow, that of hind-margin brown.

Hind wings with margin evenly rounded, fringe yellow, a narrow yellow marginal band from apex to middle of termen, with rather straight internal border. Larger part of hind wing dark blackish or greyish brown, with extensive transverse striation. Distal margin of dark area lined with iridescent scales. Discal spot weak, visible as a short, curved, white streak. Indistinct postmedial double waved or ziczac-line present in most specimens.

Underside of both wings (Figs 8, 10, 12) yellow, forewings with a tiny, black, apical spot and a short, transverse, almost straight, blackish bar from tornus towards the centre of the wing. There is a greyish-brown band between hind margin and posterior vein of cell, more or less agreeing with the dark basal area of the upper side and also a dark patch representing the apical patch of upper side. Hind wings on underside with a large, blackish-brown, oval patch, broadly touching the anterior margin near apex. Basal area of wings yellow, often suffused with darker scales. Distally a narrow, light yellow marginal band from apex to the middle of termen, basal half represented by the yellow fringe scales only.

Head with frons distinctly narrower than eye-diameter, smoothly scaled, greyish-brown, with thin white ventral margin, but with groups of upright, narrow scales at dorsal margin. Vertex with larger, yellow scales and white scales between the antennal bases, basal segments and dorsal side of lower part of antennae also white. Palps slightly up-curved, basal segment predominantly white, second and third of a light greyish-brown colour, the second edged white distally, the third segment small, tapering, with a white tip. Proboscis well developed. Antennae unipectinate, with longest branches about 8,5 times as long as the diameter of the flagellum shaft. Terminal one third of antennae simple. Patagia and anterior parts of tegulae yellow, posterior part of tegulae, thorax and abdomen greyish brown. Tibiae of hindlegs not dilated, thus without hair-pencil. Setal comb on third abdominal sternite as well as sterno-tympanal spine lacking. Tympanal organ without lacinia.

Male genitalia (Fig. 22). Valves elongate, weakly sclerotized, apex rounded, lamina internally densely setose. Valve costa, like the whole genitalia capsule, weakly sclerotized, but sacculus with a prominent and strongly sclerotized, triangular plate with an acute tip distally, inserting in an upright position close to the ventral margin of the saccular region. Basally, it is getting narrow and widens again to a rounded, dorsal bulb. Outer margin of plate and bulb scobinate and slightly setose. Length of sacculus and its process a little more than half the length of the ventral valve margin. Uncus broad, dorsally rounded, ventrally flattened, dorsally setose, slightly curved ventrad, with pointed tip, with a dense group of stiff setae near base. Socii very small, marked by a few long setae only. Gnathos with narrow lateral arms, central part a broad plate at right angles towards the lateral arms, without medial process. Transtilla a triangular, curved, cap-like plate, its tip pointing distally, with a pair of short, narrow processes arising from the proximal corners and directed caudally. Juxta a narrow plate, with a deep, v-shaped incision dorsally. Saccus narrow, strongly elongate, rounded distally.

The aedeagus club-shaped, with a stout proximal and a narrow, slightly curved distal half, the vesica with an elongate, semi-cylindrical sclerotization and a small group of 5–6 cornuti, not much differing in size. Bulbus ejaculatorius moderately large, about half the length of the aedeagus.

Diagnosis. *P. thorbeni* is in no way similar to *P. moultoni* or *P. magdelinae,* but externally quite close to *P. costa-*

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tus, the type of this species-group (Figs 13–15). Both are of the same size and the arrangement of yellow and brown pattern elements is very similar. In detail, *P. thorbeni* is distinguished from *P. costatus* in the apical forewing patch being smaller, darker und more strongly irregular. *P. costatus* has the internal surface of this patch rather grey instead of brown. *P. thorbeni* has a black, acute apical spot or streak, best seen in specimens with a reduced apical patch (Figs 9, 11). It is strongly highlighted by iridescent scales and absent in *P. costatus*. There is a curved, blackish antemedial line in *P. costatus*, absent in *P. thorbeni*.

Fringe of termen of forewings is completely yellow in *P. thorbeni* (partly grey in *P. costatus*) and there is more of the yellow ground colour distal to the brown pattern elements. In the hind wing, the tornal half is narrowly yellow in *P. thorbeni*, but brown – including fringe – in *P. costatus*. The underside is very different in both species, i.e. the large black patch of the hind wing seen in *P. thorbeni* is absent in *P. costatus*, the surface being light grey instead in the latter (Fig 15). The underside of *P. thorbeni* is much more similar to *P. magdelinae* and *P. moultoni*.

Also the male genitalia are strongly different, especially in the shape of the saccular process, which is also more similar to *P. magdelinae* (Fig 21), and cannot be mistaken.

Female unknown.

Type material. Holotype, ♂, "Indonesia, C. Sulawesi, Tambusisi mts., 1800m, 1° 45'S 121° 27'E, ii. 1996, native collector". Coll. ZFMK, coll. no. LEP 2010/471.

Paratypes. 6♂, same data as holotype; 2♂, South Sulawesi, Quarles Mountains, ca. 30km N Rantepao, Polo Polo, 2200m, 26.–28.ix.1995, leg. H. Schnitzler; 3♂, Central Sulawesi, Sempuraga (=Sampuraga), 1500–1700m, vi. 1996, G. Lecourt & J. Martin leg.; 2♂, C. Sulawesi, vic. Mamasa, 2° 57'S 119° 24'E, 17.–18.x.1995, leg. local collector (Gala); 1♂, S. Sulawesi, Puncak Palopo, 900–1300m, x.1997, leg. local collector, ex coll. Dr. R. Brechlin. Coll. ZFMK, coll. nos LEP 2010/472–476.

2♂, S. Sulawesi, Puncak Palopo, 900–1300m, ii.1998, leg. local collector, coll. M. Schaarschmidt, Leipzig, Germany.

2♂, C. Sulawesi, Mt. Tambusisi, x. 1195, native collector; 7♂, same locality, ii. 1996; 2♂, same locality, iii. 1996. Coll. K. Yazaki, Tokyo.

Further material studied. J. D. Holloway sent images of three male specimens, collected by him during the "Project Wallace" of the Royal Entomological Society. Collecting site: "Sulawesi Utara, Dumoga Bone N.P., Site 15, 1140m, 6.–8. viii.1985". According to his recommendation, these three undissected males which also show slight external differences compared to the paratypes mentioned above and which come from a locality in Northern Sulawesi rather far away from the type locality are not recorded as paratypes.

Distribution and bionomics. Probably endemic to Sulawesi, but widely distributed on the island. Specimens have been collected in February, June, September and October at elevations between 900m and 2200m a.s.l. The immature stages are unknown.

Etymology. The present new species is dedicated to Thorben Briese (Lippstadt, Germany), in recognition of his and his parents' Dr. Anette Meyer-Briese and Dr. Harald Briese valuable contribution to the taxonomic research of the author and to conservation of biodiversity.

DNA barcoding results

Results obtained from the Canadian Centre for DNA Barcoding (CCDB) revealed clear specific distances between all species involved: pairwise distances are between 3.13% and 7.25% in the *P. costatus*-group. Of the species treated in the present paper, *P. moultoni* and *P. thorbeni* exhibit the closest relationship (medial pairwise distance 3.54%).

In addition, an unusually deep divergence was found among the analysed specimens of *P. warreni* Prout, indicating a cryptic new taxon within material from Laos, Vietnam and Thailand. Morphological studies on this group are carried out at present and will be published in near future, together with a more comprehensive account on the barcoding results of the whole group. Preliminary results can be viewed under www.boldsystems.org/ *Plutodes*.

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Proclinopyga ulrichi sp. nov.: the first fossil aquatic dance fly of the subfamily Clinocerinae (Diptera: Empididae)

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Abstract. *Proclinopyga ulrichi* sp. nov. is described from Baltic amber, and represents the first definitive clinocerine fossil species. *Palaeoparamesia proosti* Meunier, 1902, considered a possible species of Clinocerinae, is transferred to the Trichopezinae.

Key words. Taxonomy, Baltic amber fossil, new species, morphology

INTRODUCTION

The Empidoidea comprise five families and numerous subfamilies of mostly predaceous flies (Sinclair & Cumming 2006). Some 150 fossil species of Empidoidea (exclusive of Dolichopodidae s.str.) are described (Evenhuis 1994; Solórzano Kraemer et al. 2005). Fossils are described from most major empidoid lineages, extending the origin of these lineages to at least the Cretaceous period (Grimaldi & Cumming 1999).

The subfamily Clinocerinae consists of primarily aquatic associated taxa, with adults mostly encountered on emergent rocks in streams and rivers (Sinclair 1995). Two fossil species have been classified as clinocerines. *Fushunempites furvus* Hong, 2002, from Eocene Chinese amber is possibly a clinocerine on the basis of the long and narrow cell r_4. Unfortunately the photo of the specimen (Hong 2002a, b) does not permit a definitive decision concerning subfamily assignment. *Palaeoparamesia proosti* Meunier, 1902 has also been viewed as a possible clinocerine. A specimen of this Baltic amber species, identified by Meunier (1908), was examined in this study and found not to represent a clinocerine (see Discussion). Consequently, the description herein of a new Baltic amber species of the recent genus, *Proclinopyga* Melander, represents the first unequivocal clinocerine fossil. The age of Baltic amber is assumed to be 40 million years (Eocene).

MATERIALS AND METHODS

To prepare the pieces for identification, the amber was cut and polished using an IsoMet® Low Speed Saw (Buehler, Lake Bluff, Illinois, USA) cutting machine and a Phoenix® Beta Grinder-Polisher (Buehler) polishing machine with SiC grinding paper for metallography, grit 800, 1200 and 2500, Microcut® Abrasive Paper (Buehler) plain backing P 4000, and paperboard. To protect the holotype of the new species the piece was embedded in synthetic resin Araldite® 2020 (XW396/XW397) (Huntsman Advanced Materials, Everberg, Belgium) (M. Solórzano Kraemer, Bonn, pers. comm. 2008).

Terms used for adult structures primarily follow those of McAlpine (1981), except for the antenna where terms of Stuckenberg (1999) were used. Homologies of the male terminalia follow those of Sinclair & Cumming (2006).

The Baltic amber specimen of *Palaeoparamesia* examined in this study was on loan from the Geoscience Centre of the University of Göttingen (Germany).

Genus *Proclinopyga* Melander

Proclinopyga Melander, 1928: 220. Type-species, *Proclinopyga amplectens* Melander, 1928 (original designation).

Diagnosis. *Proclinopyga* is distinguished from other genera of the Clinocerinae by its protruding face, bare eyes, labellum with pseudotracheae, broad wings with Sc evanescent, fifth tarsomere lacking extension, dorsal margin of the epandrium expanded with setae and female abdomen truncate with stout and ridged cercus.

***Proclinopyga ulrichi* sp. nov.** (Figs. 1, 2, 4, 5)

Type Material. Male holotype in Baltic amber, with following label data: "HOLOTYPE/ Proclinopyga/ ulrichi/ Sinclair"; "CNC DIPTERA/ # 12248"; amber is imbedded in resin with following dimensions: 11 x 9 x 6 mm;

Figs 1–3. 1. *Proclinopyga ulrichi*, habitus. 2. *Proclinopyga ulrichi*, male terminalia, postero-lateral view of right side. 3. *Palaeoparamesia proosti*, habitus.

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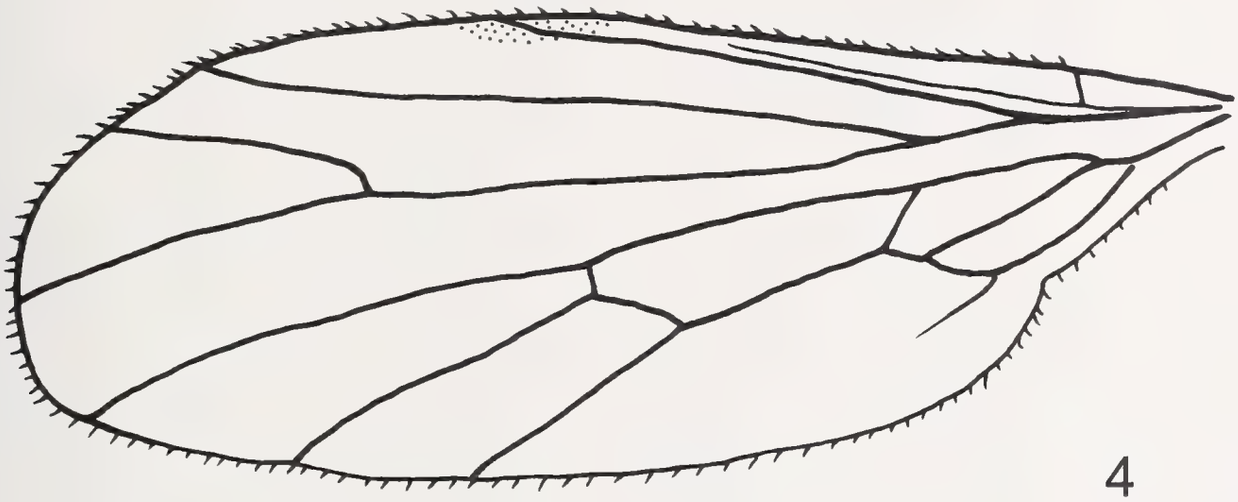
included in amber block is a male chironomid (missing abdomen). The holotype is housed in the amber collection of Dr. Hans Ulrich at the Zoologisches Forschungsmuseum A. Koenig (Bonn, Germany).

Recognition. This species (Fig. 1) is distinguished by the lengthened, attenuated apical half of the postpedicel, convoluted phallus with its hair-pin bend at mid-length and row of stout posteroventral setae on the male mid-femur.

Description. Male. Eye bare, dichoptic; lower half of face with slight protuberance in profile. Antenna with scape slightly longer than pedicel; postpedicel pointed ovate, longer than pedicel and scape combined, strongly attenuated and prolonged in apical half; arista-like stylus 1.5 times longer than postpedicel. Proboscis short; palpus club-shaped; labellum held in horizontal position, sucker-like.

Alternating biserial row of acrostichal setae, ending at



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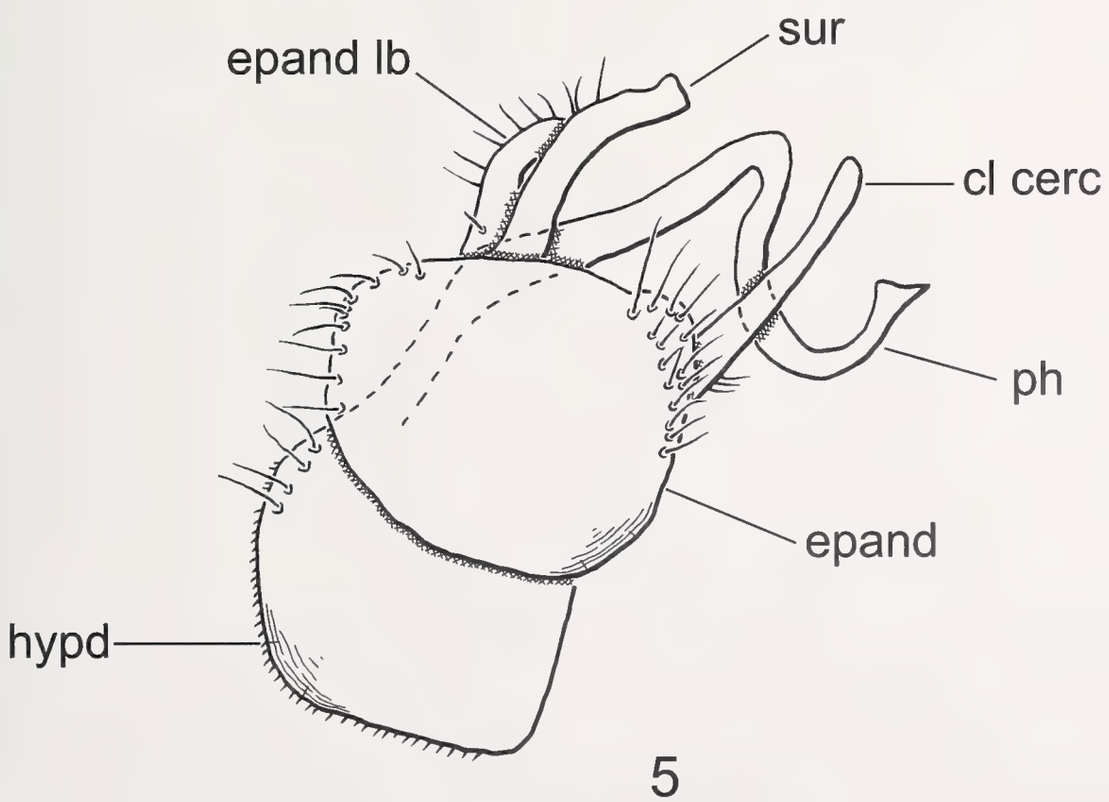

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Figs 4–5. 4. *Proclinopyga ulrichi*, wing. 5. *Proclinopyga ulrichi*, male terminalia, lateral view of right side. Abbreviations: cl cerc – clasping cercus; epand – epandrium; epand lb – epandrial lobe; hypd – hypandrium; ph – phallus; sur – surstylus.

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prescutellar depression; 6–7 dorsocentral bristles, foremost large and positioned toward postpronotal lobe; 1 postpronotal bristle; 1 presutural supra-alar bristle; 2 notopleural bristles; 2 postsutural supra-alar bristles; 1 postalar bristle; 4 scutellar bristles. Laterotergite with short, black setae in row.

Wing (Fig. 4) (length 3 mm) broad, slightly infuscate; basal costal bristle long, reaching to near humeral crossvein; anal lobe well developed; R_4 strongly divergent from R_5.

Legs with evenly scattered setae. Mid femur with posteroventral row of long, stout setae, longer than width of femur. Mid tibia bearing stout, short, erect ventral setae; one antero- and one posterodorsal setae near base. Hind tibia with row of erect dorsal and anteroventral setae on distal two-thirds.

Abdomen with tergite 6 with transverse row of 6 erect dark setae, length more than half width of abdomen. Terminalia (Figs. 2, 5): Hypandrium cone-shaped, as long as epandrium is wide. Phallus long, slender and convoluted, with strong bend at mid-length; apex slightly expanded. Epandrium with expanded posterodorsal margin, bearing long setae and setulae; epandrial lobe continuous with expanded region of epandrium, bearing long setae and attenuated apically. Surstylus closely associated with epandrial lobe; shallow notch proximal to slightly expanded and truncate apex. Clasping cercus digitiform, straight, longer than surstylus; bearing short setulae.

Female. Unknown.

Geographical Distribution and Phenology. Extant species of *Proclinopyga* are confined to the Nearctic, eastern Palearctic, and Oriental regions (Sinclair 1995). This fossil species is the only known representative of this genus in Europe and the western Palearctic Region. Adults of *Proclinopyga* are associated with running water habitats, most commonly collected in streams, creeks, and cascades. The immature stages of this genus are unknown.

Phylogenetic Relationships. *Proclinopyga* comprises ten described species and at least this many undescribed species (Sinclair 1995). The slender, highly convoluted phallus (Fig. 5) of the fossil species is most similar to extant species in North America [e.g., *P. flavicoxa* Melander, 1928 (see Sinclair 1995, fig. 13)].

Etymology. This species is dedicated to Dr. Hans Ulrich who has amassed a rich collection of little known amber species of Empidoidea.

DISCUSSION

Proclinopyga ulrichi represents the first definitive clinocerine fossil taxon. The presence of Clinocerinae in Baltic amber was first definitively stated by Ulrich (2003, table, fig. 1) and was based on the specimen described here (H. Ulrich, Bonn, pers. comm. 2008). As in other subfamilies of the Empidoidea (exclusive of Dolichopodidae s.str.), Baltic amber fossils often belong to Recent genera (see discussion by Ulrich 2003). Clinocerines appear to be underrepresented in amber compared to other groups of empidoids, likely resulting from their very close association with flowing water habitats. Adults are rarely collected away from emergent rocks in streams and rivers and they do not form aerial swarms and consequently rarely would they be associated with tree trunks and other sources of amber.

Palaeoparamesia proosti was described on the basis of a single male specimen (No. 2118) (Meunier 1902). Meunier (1908) listed two additional specimens of this species (Nos. 8437, 7786) in his monograph on Baltic amber Empididae. Only specimen No. 8437 from these original series remains in the Göttingen collection (H. Ulrich, Bonn, pers. comm. 2001). This male specimen was examined and found to be in excellent condition (Fig. 3) and conspecific with *P. proosti*. This examination revealed that *Palaeoparamesia* Meunier should be assigned to a group of several small genera currently found in the western Nearctic region and assigned to the Trichopezinae; i.e., *Boreodromia*, Nearctic species of *Apalocnemis* Philippi and two winter collected species of a genus with antennae morphologically similar to *Gloma* Meigen (Sinclair 2008). *Palaeoparamesia* is characterized by a dichoptic male head, pair of long frontal bristles (rare in empidoids, except for Hilarini), postpedicel somewhat similar to *Gloma*, Trichopezinae-like female terminalia (based on conspecific specimen in Ulrich collection), hypandrium and epandrium fused (at least partially), erect male cerci and ear-like surstyli. On the basis of similarly shaped postpedicel and dichoptic male head, *Palaeoparamesia* and the winter species near *Gloma* are most closely related. These genera will be more thoroughly examined and described in a future publication by the author.

Acknowledgements. Many thanks to Mónica Solórzano Kraemer (University of Bonn) for preparing the amber specimen. Hans Ulrich (Bonn, Germany) generously permitted the examination of his amber collection, access to literature and personal notes on the Meunier amber collection. Mike Reich (University of Göttingen) kindly arranged the loan of the amber specimen, *Palaeoparamesia proosti*. Henri Goulet (CNC – Canadian National Collection) produced the photographs of the amber inclusions. Jeff Cumming (CNC), H. Ulrich and three anonymous reviewers provided valuable comments on earlier drafts.

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Antennal sensilla of the rice hispa *Dicladispa armigera* (Olivier, 1808) (Coleoptera: Chrysomelidae)

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Abstract. Number and types of sensilla on each antennal segment of male and female adult rice hispa *Dicladispa armigera* (Olivier) (Coleoptera: Chrysomelidae) were determined based on light and scanning electron microscopic observations. The males had a significantly greater total number (ø 1828.11) of sensilla than females (ø 1764.43). Five types of sensilla, namely, sensilla chaetica, sensilla trichodea I, sensilla trichodea II, sensilla basiconica and pit or coeloconic sensilla were distinguished in both sexes. Sensilla trichodea I and II were distributed over the entire length of the antenna, whereas sensilla chaetica were observed only on the apical five flagellomeres. Methoprene affected antennal morphology by producing two-clubbed antenna (additional one at the 3rd flagellomere) and alteration in the sensilla of the last flagellomere.

Key words. Rice hispa, sensilla chaetica, sensilla trichodea I, sensilla trichodea II, sensilla basiconica, methoprene.

INTRODUCTION

The rice hispa *Dicladispa armigera* (Olivier, 1808) (Coleoptera: Chrysomelidae) occurs in South East Asia and Africa, and is one of the major pests of rice in many rice growing states of India (Deka & Hazarika 1996; Palaszek et al. 2002; Islam et al. 2004; Hazarika et al. 2005). It causes considerable damage to vegetative stages of rice resulting in yield loss of 28% in India (Nath & Dutta 1997), between 20–30% in Nepal (Dhaliwal et al. 1998) and up to 52% in deepwater rice in Bangladesh (Islam 1989); however, it may be as high as 100% in the rice transplanted post flood in Assam (Hazarika 2005). In order to manage this pest, attempts were made to identify pheromones in this insect, with mixed results (Deka & Hazarika 1997). Pheromones are not only used for survey and surveillance of insect pest but also used to manage them.

During the last three decades, insect communication through antennal sensilla has received substantial interest (Rao et al. 1990; Kumar et al. 1995; Axtell 1999). Generally, antennae are covered with huge numbers of sensilla, relevant as sensory organs (Chapman 1982). Antennal sensilla are involved in host recognition and mate or microhabitat choice by pheromone- thermo- and hygroreception (Hazarika & Bardoloi 1998; Chen et al. 2003; Ploomi et al. 2003; Marttje et al. 2004). A number of studies has been conducted on the sensilla of other coleopteran insects like flea beetles, *Phyllotetra cruciferae* (Goeze, 1777), *Psylliodes punctulata* Melsheimer, 1847, *P. affinis* (Paykull, 1799) and *Epitrix cucumeris* (Harris, 1851) (Ritcey & McIver 1990); however, currently there is no information available describing the sensilla of the rice hispa. Accordingly, the present study was undertaken in order to determine the number and types of sensilla on each antennal segment of male and female adults of *D. armigera*.

MATERIALS AND METHODS

For determination of number of sensilla, male and female antennae of field collected adults were fixed separately in carnoy-lebrun fixative for 30 min and washed for 10 minutes in each of the 30%, 50% and 70% alcohol. The antennae were then allowed to remain for twenty minutes in each of the 90% and absolute alcohol, after which they were again passed through xylene and cleared in clove oil. These were then mounted in DPX. Sensilla were observed under the compound microscope at 100X, 400X and 1000X magnification in oil and were counted on each segment following the method of Ramaswamy & Gupta (1981).

Table 1. Estimated number (Mean±S.E.) of sensilla on each antennal segment of adult male and female *D. armigera.*

Segment	Male	Female	t-value
Scape	25.25±0.29^{i}	21.23±0.37^{i}	8.95**
Pedicel	28.45±0.32^{h}	24.99±0.28^{h}	8.77**
Flagellum (Fl)			
Fl 1	19.28±0.25^{k}	18.02±0.29^{j}	2.95**
Fl 2	22.48±0.30^{j}	21.48±0.30^{i}	2.48*
Fl 3	33.66±0.32^{g}	26.69±0.30^{g}	15.15**
Fl 4	61.67±0.65^{f}	56.77±0.38^{f}	6.82**
Fl 5	220.43±0.34^{e}	223.25±0.35^{e}	-6.53**
Fl 6	265.20±0.41^{d}	258.36±0.49^{d}	9.79**
Fl 7	302.26±0.33^{c}	295.73±0.40^{c}	11.99**
Fl 8	336.11±0.28^{b}	332.84±0.39^{b}	8.15**
Fl 9	490.84±0.53^{a}	485.07±0.46^{a}	7.47**
S.Ed. (±)	0.05	0.52	
C.D. $_{0.05}$	0.11	1.04	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

For determination of types of sensilla, the antennae were fixed for six hours in carnoy-lebrun fixative and mounted in DPX (Schafer & Sanchez 1976). Based on the morphology of the sensilla, sensilla were classified into types. Sizes of these sensilla were measured with the ocular micrometer and readings were converted into µm. We also bleached the antennae in 2% hydrogen peroxide for 24 hr. Permeable areas of antennae were examined under bright field illumination using crystal violet method (Slifer 1960). One hundred 6–12 h old pupae were treated with 5 ppm methoprene (Altosid SE, 62.5% RS methoprene, Zoecon, Palo Alto, CA). Twenty adultoids were randomly selected for this study.

Scanning electron microscopy studies of the antennae of the adults and adultoids were undertaken by following the method described in Hazarika & Bardoloi (1998). Antennae were dissected out of the head and cleaned in distilled water, which were then fixed in buffered glutaraldehyde. They were dehydrated by passing through a series of acetone starting from 30% to 100%. On drying, antennae were placed on stubs using double sided, scotch tapes and coated with gold-palladium in a sputterer (JEOL, JFC 1100, Japan) for 5–10 min. The specimens were scanned in a scanning electron microscope (JEOL, 35-CF, Japan) at 15 KV and photographs were taken for each of the specimens.

RESULTS

The clubbed antennae of adult specimens consisted of scape, pedicel and nine sub-segmented flagellum, each sub-segment is called flagellomere, the first flagellomere being the longest (0.30±0.02 mm) while eighth is the shortest (0.15±0.02 mm). A spine is present on the ventral surface of the scape though the rest of the antenna is free from such spines. Scanning electron microscopic studies revealed the presence of scales on the scape, pedicel and first to sixth flagellomere. The numbers of sensilla in male and female adults of *D. armigera* are shown in Tab. 1. In male and female antennae, the distal segments are densely covered with sensilla. There is a distinct difference in shape of the 9th flagellomere between the male and female. In each segment as well as sub-segments, the male adults had a significantly greater number of sensilla than its female counterpart (Tab. 1) except on the fifth flagellomere, where it was reverse.

The mean number of sensilla per unit area is shown in Tab. 2. Both in male and female, the maximum population was observed on the eighth and ninth flagellomere (7.11±0.03 mm^2 and 8.89±0.03 mm^2, respectively) and the lowest was observed on the scape (0.37±0.01 mm^2 and 0.29±0.01 mm^2, respectively). Though density of sensilla on each segment was significantly higher in the male, but on the fifth to ninth flagellomere, it was reverse (Tab. 2).

Table 2. Mean±S.E. density of sensilla (number/mm^2) on each antennal segment of adult male and female *D. armigera.*

Segment	Male	Female	t-value
Scape	0.37±0.01^{i}	0.29±0.01^{j}	10.28**
Pedicel	0.60±0.01^{h}	0.48±0.01^{i}	9.45**
Flagellum (Fl)			
Fl 1	0.42±0.01^{i}	0.35±0.01^{j}	4.35**
Fl 2	0.63±0.02^{h}	0.57±0.01^{h}	2.80*
Fl 3	0.96±0.01^{g}	0.81±0.01^{g}	7.77**
Fl 4	2.03±0.02^{f}	2.09±0.03^{f}	-1.94^{NS}
Fl 5	4.49±0.02^{f}	5.26±0.02^{e}	-26.47**
Fl 6	5.98±0.16^{d}	6.30±0.04^{d}	-1.89^{NS}
Fl 7	6.15±0.02^{c}	7.65±0.03^{c}	-48.52**
Fl 8	6.95±0.03^{b}	7.75±0.03^{b}	-17.18**
Fl 9	7.11±0.03^{a}	8.89±0.03^{a}	-42.61**
S.Ed. (±)	0.07	0.03	
C.D. $_{0.05}$	0.14	0.07	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at P < 0.05. Means followed by the same letter shown in superscript(s) are not significantly different. Means within the rows are followed by * and ** are significantly different at p < 0.01 and p < 0.05, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 3. Size (Mean±S.E., length x width in µm) of sensilla trichodea I on each antennal segment of adult male and female *D. armigera.*

Segment	Male		Female		t-value	
					Length	Width
Scape	41.46±0.03^{a} x 1.86±0.02^{cd}		39.52±0.04^{a} x 1.83±0.02^{cd}		41.07**	-2.27*
Pedicel	39.23±0.08^{b} x 1.80±0.01^{d}		38.50±0.07^{c} x1.74±0.02^{e}		13.70**	2.46*
Flagellum (Fl)						
Fl 1	36.50±0.09^{h} x 1.74 ±0.02^{e}		36.56±0.05^{f} x 1.74±0.02^{e}		-0.53^{NS}	0.01^{NS}
Fl 2	37.18±0.07^{g} x 1.81±0.01^{cd}		35.21±0.05^{i} x 1.81±0.01^{d}		32.91**	0.42^{NS}
Fl 3	37.46±0.07^{f} x 1.84±0.02^{cd}		35.80±0.03^{h} x 1.83±0.02^{cd}		23.55**	0.15^{NS}
Fl 4	37.84±0.12^{e} x 1.81±0.01^{cd}		36.37±0.16^{g} x 1.84±0.02^{cd}		9.53**	-1.08^{NS}
Fl 5	37.87±0.18^{e} x 1.85±0.01^{c}		38.00±0.05^{e} x 1.86±0.02^{bc}		-0.70^{NS}	-0.55^{NS}
Fl 6	38.00±0.07^{de} x 1.89±0.01^{b}		38.10±0.04^{de} x 1.90±0.02^{ab}		1.91^{NS}	0.31^{NS}
Fl 7	38.22±0.06^{de} x 1.90±0.02^{b}		38.22±0.04^{cd} x 1.89±0.01^{ab}		0.01^{NS}	0.41^{NS}
Fl 8	38.51±0.06^{c} x 1.92±0.02^{b}		38.52±0.04^{b} x 1.99±0.01^{ab}		26.17^{NS}	
0.82^{NS}						
Fl 9	38.54±0.07^{c} x 1.96±0.01^{a}		38.63±0.03^{b} x 1.92±0.01^{a}		24.52^{NS}	6.56**
S.Ed. (±)	0.13	0.02	0.09	0.02		
C.D. $_{0.05}$	0.25	0.04	0.18	0.05		

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at p < 0.05. Means followed by the same letter shown in superscript(s) are not significantly different. Means within the rows are followed by * and ** are significantly different at p < 0.01 and p < 0.05, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 4. Estimated number (Mean±S.E.) of sensilla trichodea I on each antennal segment of adult male and female *D. armigera.*

Segment	Male	Female	t-value
Scape	2.51±0.37^{j}	1.88±0.42^{j}	1.29^{NS}
Pedicel	5.81±0.52^{hi}	5.50±0.50^{h}	0.46^{NS}
Flagellum (Fl)			
Fl 1	3.93±0.50^{ij}	3.45±0.21^{ij}	0.83^{NS}
Fl 2	6.44±0.48^{h}	5.02±0.47^{hi}	2.02^{NS}
Fl 3	12.72±0.62^{g}	7.69±0.58^{g}	7.61**
Fl 4	21.82±0.66^{f}	11.46±0.52^{f}	12.11**
Fl 5	141.77±0.66^{e}	137.22±0.82^{e}	3.96**
Fl 6	155.43±0.66^{d}	176.46±0.84^{d}	-16.56**
Fl 7	181.34±0.79^{c}	182.43±0.82^{c}	-1.13^{NS}
Fl 8	209.44±1.97^{b}	204.10±0.64^{b}	2.74^{NS}
Fl 9	235.03±0.69^{a}	198.29±0.76^{a}	31.57**
S.Ed. (±)	1.17	0.89	
C.D. $_{0.05}$	2.32	1.76	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different. Means within the rows are followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$ probability level, respectively (Student t-test; t-values are shown against each pair; d.f. < 49).

Table 5. Size (Mean±S.E., length x width in µm) of sensilla trichodea II on each antennal segment of adult male and female *D. armigera.*.

Segment	Male		Female		t-value	
					Length	Width
Scape	38.11±0.23^{a} x 1.73±0.01^{cd}		36.52±0.05^{a} x 1.70±0.03^{def}		6.77**	0.87^{NS}
Pedicel	36.52±0.09^{b} x 1.71±0.01^{de}		34.75±0.04^{b} x1.68±0.02^{ef}		20.00**	1.33^{NS}
Flagellum (Fl)						
Fl 1	30.03±0.05^{e} x 1.69 ±0.01^{e}		29.12±0.04^{f} x 1.67±0.01^{f}		11.60**	1.10^{NS}
Fl 2	31.45±0.01^{d} x 1.73±0.01^{cd}		31.04±0.06^{d} x 1.73±0.01^{de}		5.93**	0.31^{NS}
Fl 3	32.06±0.09^{c} x 1.72±0.01^{cd}		31.73±0.04^{e} x 1.74±0.01^{cd}		2.83*	-1.59^{NS}
Fl 4	32.15±0.10^{c} x 1.73±0.02^{cd}		30.04±0.04^{e} x 1.74±0.02^{cd}		22.25**	-0.46^{NS}
Fl 5	25.05±0.12^{i} x 1.73±0.01^{cd}		26.51±0.06^{h} x 1.78±0.02^{abc}		-8.97**	-1.64^{NS}
Fl 6	27.73±0.12^{g} x 1.75±0.01^{c}		26.83±0.07^{g} x 1.74±0.02^{bcd}		7.44**	-0.13^{NS}
Fl 7	28.24±0.05^{f} x 1.78±0.01^{b}		25.01±0.04^{i} x 1.78±0.01^{abc}		40.29**	-0.43^{NS}
Fl 8	26.17±0.07^{h} x 1.80±0.01^{b}		24.30±0.04^{j} x 1.79±0.01^{ab}		26.57**	1.75^{NS}
Fl 9	24.52±0.06^{j} x 1.87±0.01^{a}		24.04±0.03^{k} x 1.80±0.01^{a}		6.77**	8.11**
S.Ed. (±)	0.15	0.01	0.07	0.02		
C.D. $_{0.05}$	0.29	0.02	0.13	0.04		

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 6. Estimated number (Mean±S.E.) of sensilla trichodea II on each antennal segment of adult male and female *D. armigera*

Segment	Male	Female	t-value
Scape	22.61±0.49^{f}	19.31±0.69^{g}	4.10**
Pedicel	22.92±0.56^{f}	19.63±0.59^{g}	4.27**
Flagellum (Fl)			
Fl 1	15.61±0.67^{h}	14.76±0.46^{h}	0.38^{NS}
Fl 2	16.01±0.55^{h}	16.33±0.53^{h}	-0.44^{NS}
Fl 3	20.10±0.53^{g}	20.10±0.62^{g}	-0.01^{NS}
Fl 4	39.88±0.61^{e}	45.37±0.74^{f}	-5.55**
Fl 5	63.90±0.61^{d}	64.68±0.66^{e}	-0.84^{NS}
Fl 6	73.66±0.61^{c}	70.81±0.62^{d}	-2.52*
Fl 7	83.21±0.62^{b}	79.10±0.70^{c}	3.28**
Fl 8	83.37±0.84^{b}	90.75±0.82^{b}	7.19**
Fl 9	136.75±0.77^{a}	156.84±0.73^{a}	-19.07**
S.Ed. (±)	0.89	0.93	
C.D. $_{0.05}$	1.76	1.84	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 7. Size (Mean±S.E., length x width in µm) of sensilla chaetica on each antennal segment of adult male and female *D. armigera.*

Segment	Male		Female		t-value	
					Length	Width
Scape	–		–		–	–
Pedicel	–		–		–	–
Flagellum (Fl)						
Fl 1	–		–		–	–
Fl 2	–		–		–	–
Fl 3	–		–		–	–
Fl 4	–		–		–	–
Fl 5	30.15±0.19^{e} x 2.70±0.02^{d}		32.24±0.05^{c} x 2.74±0.01^{d}		-22.17 **	-2.15 *
Fl 6	33.41±0.06^{d} x 2.86±0.02^{c}		32.99±0.05^{d} x 2.89±0.05^{c}		7.26 **	-0.64^{NS}
Fl 7	34.11±0.06^{c} x 2.94±0.02^{b}		33.50±0.04^{c} x 2.85±0.02^{c}		11.79 **	3.83 **
Fl 8	37.57±0.06^{b} x 3.00±0.03^{b}		38.40±0.04^{b} x 2.99±0.03^{b}		-11.92 **	0.28^{NS}
Fl 9	38.15±0.06^{a} x 3.12±0.02^{a}		38.70±0.03^{a} x 3.10±0.03^{a}		-6.67 **	0.67^{NS}
S.Ed. (±)	0.09	0.03	0.06	0.04		
C.D. $_{0.05}$	0.18	0.06	0.12	0.08		

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Table 8. Estimated number (Mean±S.E.) of sensilla chaetica on each antennal segment of adult male and female *D. armigera.*

Segment	Male	Female	t-value
Scape	–	–	–
Pedicel	–	–	–
Flagellum (Fl)			
Fl 1	–	–	–
Fl 2	–	–	–
Fl 3	–	–	–
Fl 4	–	–	–
Fl 5	14.76±0.60^{d}	21.35±0.63^{d}	-6.33**
Fl 6	36.58±0.61^{c}	10.83±0.62^{e}	29.58**
Fl 7	37.84±0.58^{c}	32.34±0.61^{c}	6.05**
Fl 8	42.55±0.66^{b}	37.99±0.68^{b}	5.45**
Fl 9	119.01±0.79^{a}	130.15±0.70^{a}	-12.06**
S.Ed. (±)	0.92	0.91	
C.D. $_{0.05}$	1.84	1.82	

SE = standard error, sample size = 50. Means within columns are separated by Duncan's Multiple Range Test (DMRT) at $p < 0.05$. Means followed by the same letter shown in superscript(s) are not significantly different; means within the rows followed by * and ** are significantly different at $p < 0.01$ and $p < 0.05$, respectively (Student t-test; t-values are shown against each pair; d.f. = 49).

Based on morphology, sensilla trichodea (ST) I, ST II, sensilla chaetica (SC), sensilla basiconica (SB) I and coeloconic sensilla were identified in both sexes of the insect. The ST I and II were numerous and observed over the entire length of the antennae whereas SC were observed only on the apical five flagellomeres. In addition, some sensilla suspected to be thermoreceptors (Tr) were also observed on scape, pedicel and some flagellomeres.

The ST I pointed distally and curved towards the antennal shaft. It is a slender structure, which tapers gradually into a very sharp point at the distal end. In males, the lengths of ST I varied from 36.50 ± 0.09 µm to 41.46± 0.03µm. Likewise, their widths varied from 1.74± 0.02 µm to 1.96± 0.01 µm. In female, the lengths varied from 35.21± 0.05 µm 39.52± 0.04 µm and their widths varied from 1.74± 0.02 µm to 1.99± 0.01 µm (Tab. 3). The highest population of ST I was observed on the ninth flagellomere (235± 0.03± 0.69) and the lowest was observed on the scape (2.51± 0.37) in males, whereas in females, the highest population was observed on the eighth flagellomere (204.10± 0.64), and the lowest was observed on the scape (1.88 ± 0.42) (Tab. 4).

The ST II were also similar to ST I except that they were unaffected when a solution of crystal violet was applied. It might be due to non- permeability of the senisilla to crystal violet. In males, the lengths of ST II varied from 24.52±0.06 to 38.11±0.23 µm (Tab. 5). Likewise their widths varied from 1.69±0.01 to 1.87 ± 0.01 µm. In females, their lengths varied from 24.04 ± 0.03 to 36.52 ± 0.05 µm and their widths varied from 1.67±0.01 to 1.80±0.01 µm.

The highest number of ST II was observed on the ninth flagellomere (136.75 ± 0.77) and lowest on the first flagellomere (15.6±0.67) in males. Likewise, in females also the highest number of ST II was observed on the ninth flagellomere (156.84 ± 0.73) and the lowest was observed on the first flagellomere (14.76 ± 0.46) (Tab. 6).

The SC were pointed distally and projected outward from a socket at an approximate angle of 50°, thick-walled and longitudinally grooved. They were restricted to the terminal five flagellomeres and were unaffected when a solution of crystal violet was applied. In males, their lengths varied from 30.15±0.09 to 38.17±0.06 µm (Tab. 7), whereas in females they varied from 32.24 ±0.05 to 38.70± 0.03 µm. In male and female, the highest number of SC was observed on the ninth flagellomere and the lowest was observed on the fifth flagellomere (Tab. 8).

A few sensilla basiconica (SB) were present in different flagellomere of *D. armigera*. SB are smaller than ST measuring 5–6 µm, wall being porous. Pit or coeloconic sensilla are also present on the antennae, however, details of their structure were not studied.

After application of growth regulator, methoprene, some deformities not only on the antennal structure but also on the sensillar morphology were observed; the 4th flagellomere got deformed. This is very prominent on the tip of the ninth flagellomere where SC were observed to be disoriented (Baishya 1992).

DISCUSSION

Densely covered distal segments of the antennae as observed here are also present in many other insects like *Blatella germanica* (Linnaeus, 1767) (Ramaswamy & Gupta 1981, Wheeler & Gupta 1986), *Croesia curvala* (Kearfott, 1907) (Langmaid & Seabrook 1985), *Bootettix argentatus* Bruner, 1890 (Chapman & Fraser 1989), *Geotrupes auratus* Motschulsky, 1858 (Inouchi et al. 1987) and *Homoeosoma electellum* (Hulst, 1887) (Faucheux 1995), and four hemipteran species (Usha Rani & Madhavendra 2005). Palpation conducted with the distal segments of antenna may provide an explanation for this pattern.

On the scape, pedicel and three flagellomeres (first to third), males had significantly greater number of sensilla per unit area than females. However, from the fourth to ninth flagellomere, females had a greater number of sensilla per unit area than males; a similar pattern was reported by Ritcey & McIver (1990) in case of *Psylloides punctulata* and *P. affinis*. A study by Usha Rani & Madhavendra (2005) suggested that sensillae in scape and pedicel may not be used in sensory perception, which remains however to be tested critically.

Similar to *Dicladispa armigera,* terminal segments of antennae covered with ST I and ST II were also reported in *Homoeosoma electellum* (Faucheux 1995), *Phothorimaea operculella* (Zeller, 1873) (Sharaby et al. 2002), *Helicoverpa armigera* (Hübner, 1808) (Wang et al. 2002). Bromely et al. (1980) stated that the ST at the antennal tips of aphids have a contact chemosensory function, and may be involved in gustation of the plant surface, which might be the case in the insect studied here as well.

The population of ST I was highest on the ninth flagellomere in males, whereas in the female it was on the eighth flagellomere. This kind of variation in ST I population may be associated with specific function performed by the sensilla. Similar cases were also recorded in *Trichoplusia ni* (Hübner, 1803) (Mayer et al. 1981), *Grapholitha molesta* (Busck, 1916) (George & Nagy 1984), *Hypera postica* (Gyllenhal, 1813) (Bland 1981). However, in case of both males and females, the ST II population was highest on the ninth flagellomere, which was also reported by Bland (1981) in *Hypera postica*, by Kapoor (1985) in *Paragnetina media* (Walker, 1852) and by Ritcey & McIver (1990) in flea beetles. SC is a common type usually encountered in many insects (Ilango 2000). The presence of SC on antennae was also reported by Ritcey & McIver (1990) in the flea beetles, *P. cruciferae, P. punctulata, P. affinis* and *E. cucumeris.*

As Hazarika & Baishya (1996) showed, application of methoprene induced morphogenesis in *D. armigera*; however, only the fourth and the last flagellomere were affected. The cause of the selectivity of this effect is unclear up to now. Hormonal regulation of antennal sensilla is reported for many insects (Wheeler & Gupta, 1986; Yamamoto-Kihara et al. 2004). Injection of a neurohormone, [His^7]-corazonin, reduced the number of coeloconic sensilla in *Locusta migratoria.* A similar study on *D. armigera* is also required since it could help to clarify the causal network in the development of the antennal sensilla pattern.

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Christoph Moning, Thomas Griesohn-Pfleger & Michael Horn (2010). Grundkurs Vogelbestimmung: Eine Einführung in die Beobachtung und Bestimmung unserer heimischen Vögel. 422 pp., Quelle & Meyer Verlag GmbH & Co, Wiebelsheim, ISBN-10: 3494014167, ISBN-13 978-3494014166, 19,95 €.

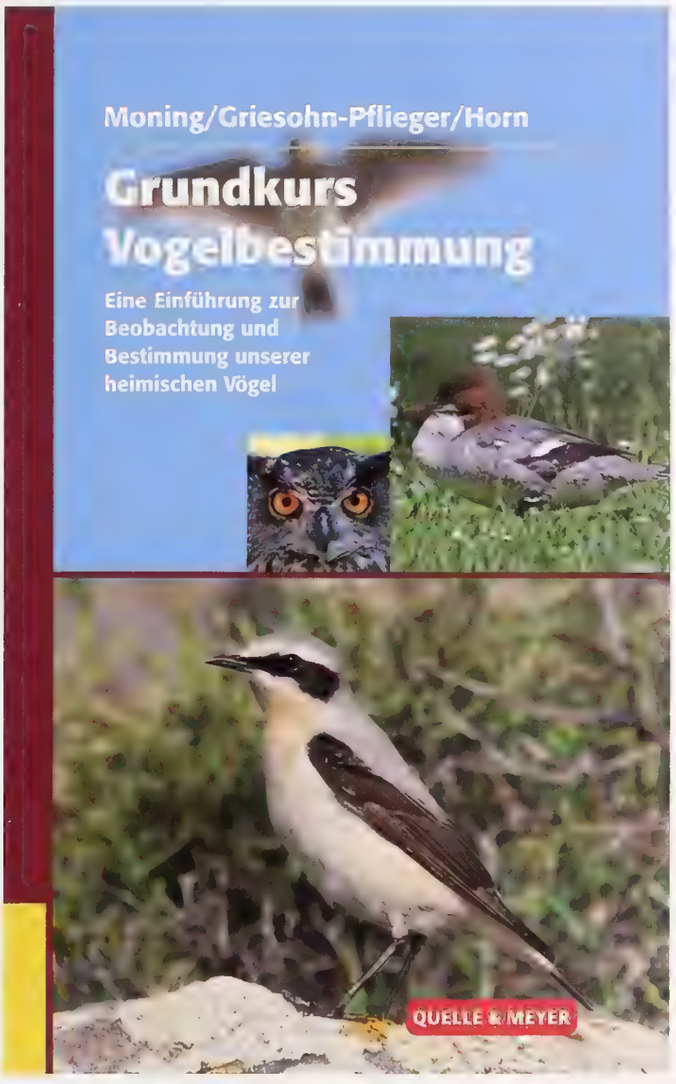
Facilitating the access to birdwatching by a book is not particularly new. There are examples from anglophone countries as well as from Germany (e.g. "Vögel beobachten" by E. Bezzel). However, "Grundkurs Vogelbestimmung" (Basic course bird identification) is particular up to date and specific to today's internet generation. The book is part of a new series of basic courses on field identification of different taxonomic groups edited by the same publishing house.

The book is divided into two major parts. The Chapters 1–12 set the general part; the second offers a surprisingly extensive insight into all central European bird families. Single chapters are rather short, the text is interrupted by boxes and figures and invites the reader to skim and browse.

The general part includes everything from equipment (binoculars, literature sources, appropriate clothes etc.) to an introduction to avian behaviour, bioacoustics, and especially to the Where, How and When of birdwatching. These chapters are the strengths of the book, and the experience of the authors who regularly work as tour guides is quite obvious. They have a good sense of humour when combining a cold drink and illustrated bird books as necessary equipment to reflect their own observations (figure on p. 21). However, a Wikipedia definition should never be cited when explaining complex issues as the handicap principle (p. 76).

The chapter on "Systematics and Taxonomy" is praiseworthy. Contributing author Daniel Lingenhöhl does not really give an explanation of these terms, but explains on five and a half pages – necessarily only rudimentary – "binary nomenclature" or the "biological species concept". Some shortcomings can be overlooked here. The author exemplifies the changing character of this scientific field by some huge changes in avian higher taxa systematics. Sadly, his explanation on using italics for scientific names is not completely correct and it is even more regrettable that in some parts of the further text not even the correct parts of his remarks were respected (p. 133 ff. subfamilies wrongly italicised, p.137 genus *Branta* not in italics).

In the conservation chapter, concepts in Germany are compared to those in some neighbouring countries. Many aspects the authors rise are certainly true but perhaps it would have been wiser to generalize a little bit less and



give this issue more space. Feeding birds might be fun but its value for conservation is at least controversial. The figure on page 125 is wrongly marked (it is a "Rotkopfwürger", "Rotstirnwürger" is an African species).

The second part is systematically ordered by Central European bird families although this order does not seem to be very consistent as non-passerines follow a generally rather conservative concept while passerines are rather ordered by new findings. There are good, compact introductions for every family and therein focus is on the most common birds so that beginners are not unnecessarily confused. Short texts and arrows in the pictures complement information from classical bird guides although some overlap cannot be denied. Graphics on the topography of many different birds increase the learning effect; observation hints enrich the text. However, the authors forgot the huge population of Melodious warblers in Rhineland-Palatinate and more important one should never throw swifts in the air that were found on the ground. The authors may have to take the responsibility for some broken bones in swifts.

So, what's missing? Not much, maybe the unloved glossary but "carpal joint" (Carpalgelenk) and even "taxon" might not be that easy to understand for the beginner. A few more internet sources and examples from Austria and Switzerland would make a broader distribution easier.

There is a growing attention for "citizen science" in organismic biology. The participation of non-professionals has a long history in the study of birds – many important long-term monitoring schemes would be impossible without the help of these so called amateurs. Scientific societies miss young people and there is hardly a scientist who does not complain about lacking public awareness of his or her field. Therefore the book is not only recommended for beginners but also to those who want to know how to teach their ornithological knowledge and for those Non-Ornithologists who look for stimulations how to prepare the popular science aspect of their organisms in an exemplary way.

Darius Stiels
Zoologisches Forschungsmuseum Alexander Koenig, Bonn

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Bonn zoological Bulletin (BzB)

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Parenti RP (2008) A phylogenetic analysis and taxonomic revision of ricefishes, *Oryzias* and relatives (Beloniformes, Adrianichthyidae). Zoological Journal of the Linnean Society 154: 494–610

Sullivan J (1994) *Bufo boreas*. In: Fire Effects Information System (U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory). Online at http://www.fs.fed.us/database/feis/animals/amphibian/bubo/all.html last accessed on December 28, 2009

Sztencel-Jablonka A, Jones G, Bogdanowicz W (2009) Skull morphology of two cryptic bat species: *Pipistrellus pipistrellus* and *P. pygmaeus* – a 3D geometric morphometrics approach with landmark reconstruction. Acta Chiropterologica 11: 113–126

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